# Water Power

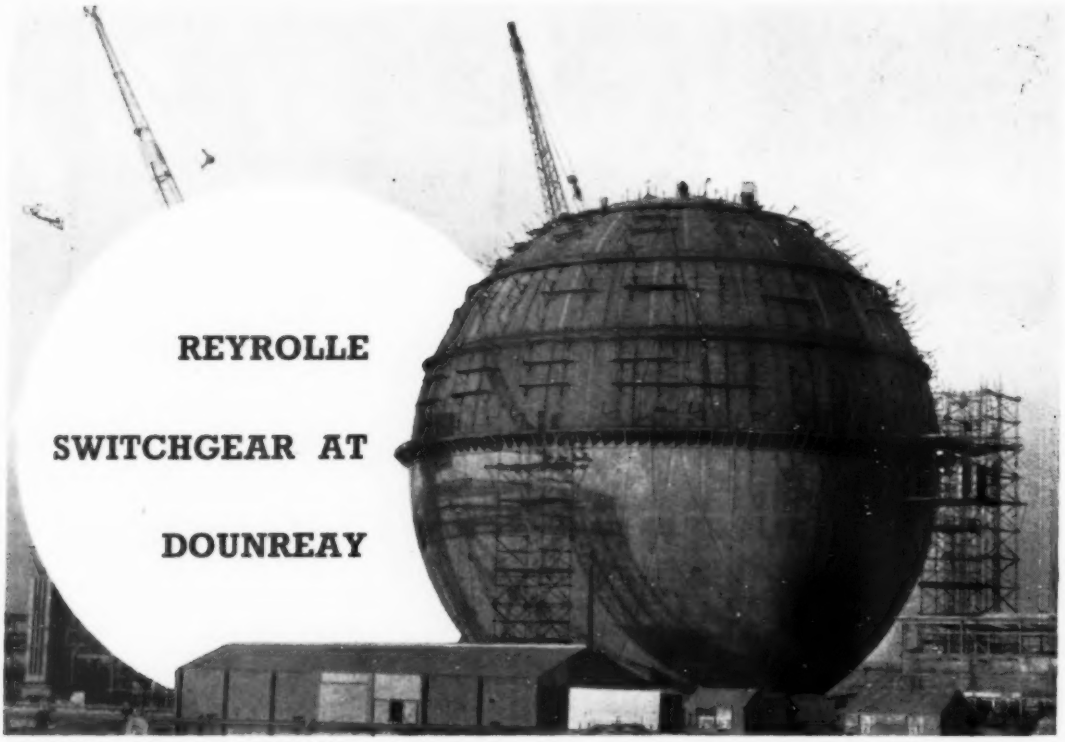
INTERNATIONAL DEVELOPMENT OF HYDRO-ELECTRIC POWER

PRICE 2/6 FEBRUARY 1958

'ENGLISH ELECTRIC' designs and manufactures water turbine generators for high, medium and low head applications and also electrical distribution and transformation equipment for power stations all over the world.

'ENGLISH ELECTRIC'
hydro-electric equipment

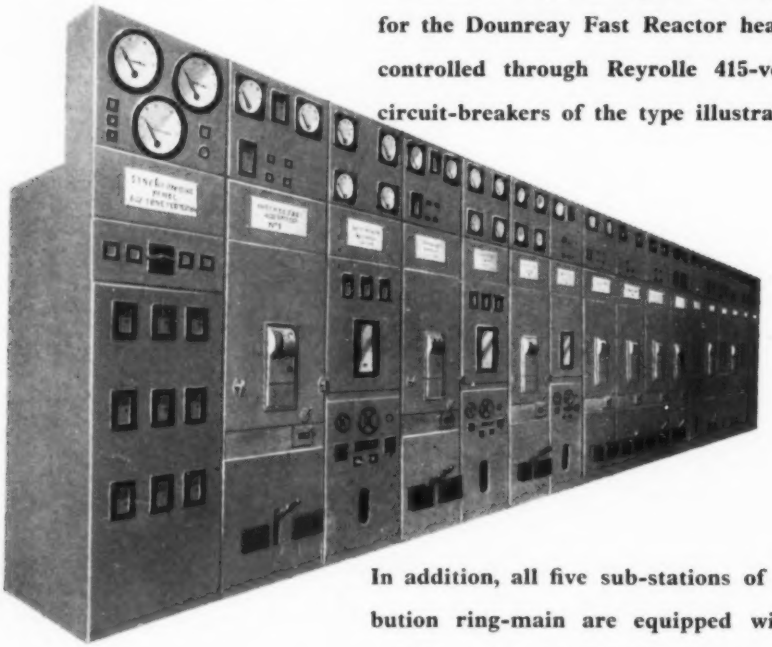
THE ENGLISH ELECTRIC COMPANY LIMITED, MARCONI HOUSE, STRAND, LONDON, W.C.2
Hydro-electric Department, Stafford, England
WORKS: STAFFORD · PRESTON · ROBY · RUGBY · LIVERPOOL · ACCRINGTON



# REYROLLE SWITCHGEAR AT DOUNREAY

*Photograph by courtesy of the U.K.A.E.A*

**The electro-magnetic liquid-metal pumps and other services for the Dounreay Fast Reactor heat-exchanger system are controlled through Reyrolle 415-volt 31·5-MVA air-break circuit-breakers of the type illustrated.**

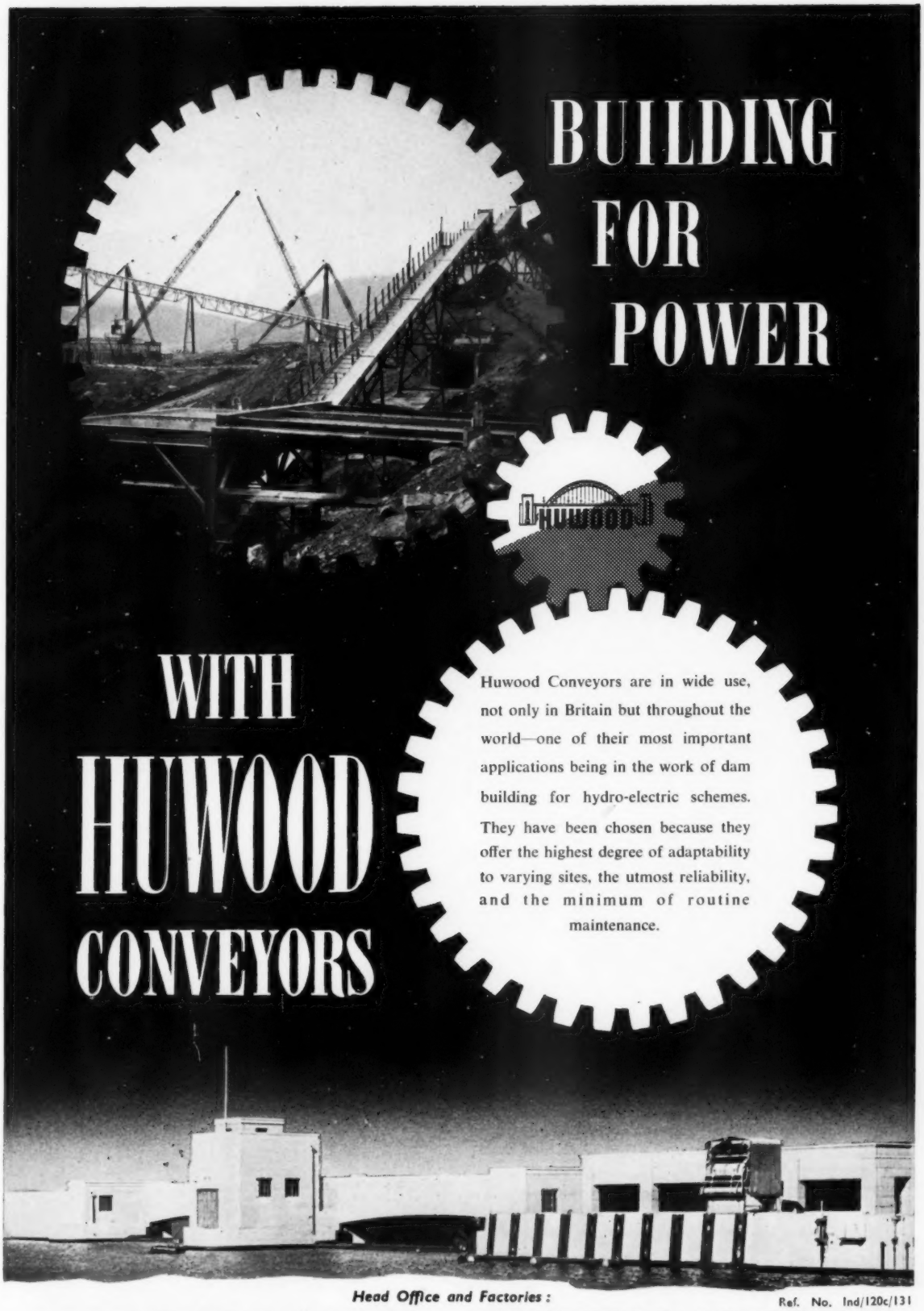


*17-panel switchboard comprising Reyrolle type-S22A air-break circuit-breakers with associated control cubicles.*

**In addition, all five sub-stations of the main 11-kV distribution ring-main are equipped with Reyrolle metalclad switchboards with 350-MVA horizontal draw-out oil-break circuit-breakers.**

**Reyrolle**

A. Reyrolle & Co. Ltd · Hebburn · County Durham · England


BUILDING
FOR
POWER
HUWOOD
WITH
HUWOOD
CONVEYORS
Huwood Conveyors are in wide use, not only in Britain but throughout the world—one of their most important applications being in the work of dam building for hydro-electric schemes. They have been chosen because they offer the highest degree of adaptability to varying sites, the utmost reliability, and the minimum of routine maintenance.

*Head Office and Factories:*

Ref. No. Ind/120c/131

**HUGH WOOD & CO LTD - GATESHEAD-ON-TYNE 11**

**INDUSTRIAL & EXPORT OFFICE: DASHWOOD HOUSE, 69, OLD BROAD STREET, LONDON, E.C.2**

member of the Glover Group

*BRECO 7½ ton, Standard Single Motor Radial Travelling Cableway, installed in Colombia for the construction of the Anchicaya Dam.*

BRECO Ropeways and Cableways have been supplied and installed for operation under most extreme climatic and topographical conditions throughout the world.

BRECO—Sole Manufacturers of 'Travelift' Cableways, outside the North American Continent. 'Travelifts' are especially suited to high speed heavy construction work.

*Literature available on request.*

BRITISH ROPEWAY ENGINEERING CO. LTD. Plantation House, Mincing Lane, E.C.3. Tel: Mincing Lane 7901. Tel. Address: Boxhauling, Fen, London.

# Kariba—largest turbine contract in Africa—to Boving

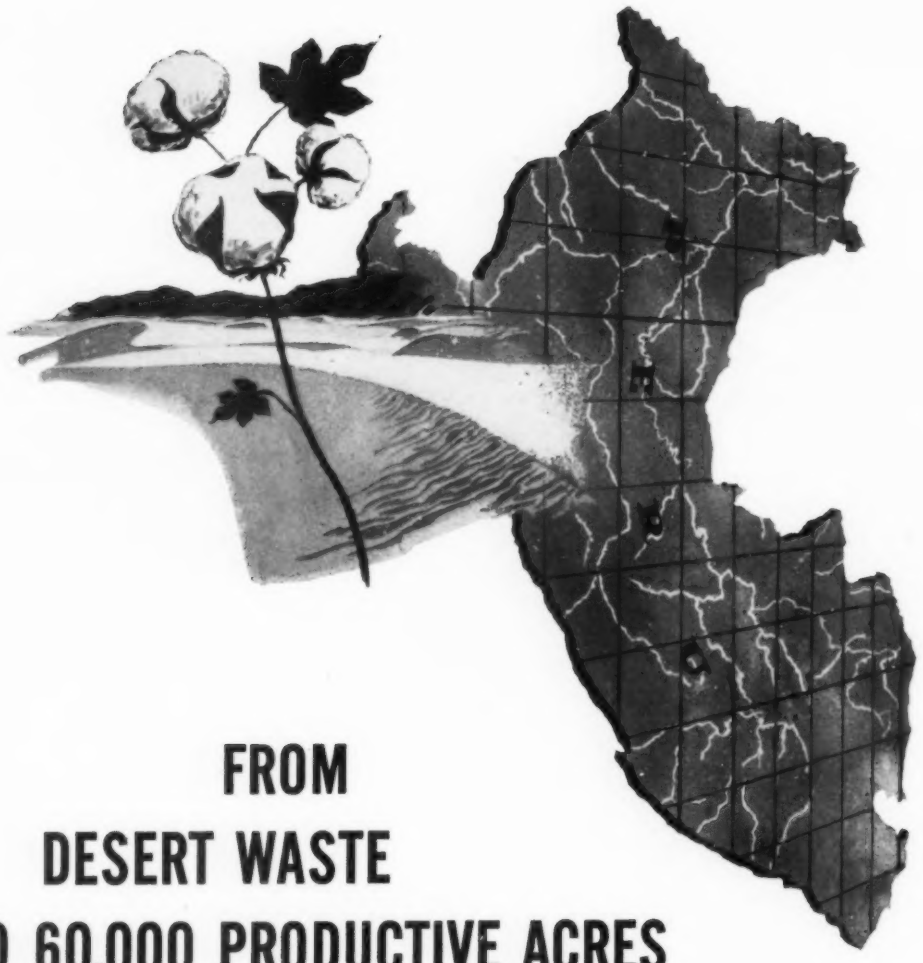
for five Vertical Francis Turbines,
each of 140,000 H.P.
under a head of 282 ft.
The contract includes manufacture,
delivery, site erection and
commissioning.



*SECTION THROUGH UNDERGROUND POWER HOUSE*

**Boving**
& COMPANY LIMITED

**WATER POWER ENGINEERS,** *56 KINGSWAY, LONDON, W.C.2.*



# FROM DESERT WASTE TO 60,000 PRODUCTIVE ACRES

## THROUGH INTERNATIONAL ENGINEERING...

Nearing completion in northern Peru's Rio Quiroz basin is the San Lorenzo Dam, a massive earth-fill structure that will impound a quarter of a billion cubic meters of water behind its quarter-mile span . . . water to irrigate 60,000 acres of new land through a modern system of canals and laterals.

With sufficient water to bring desert soil to life, farmers will grow premium grade long staple cotton for world markets . . . other crops for local consumption. Water from the San Lorenzo reservoir will also stabilize the irrigation needs of an additional 60,000 acres of farm land now subject to severe droughts and consequent crop losses.

Like so many other water and power projects throughout the world, the Rio Quiroz Irrigation Project was designed and engineered by International Engineering.

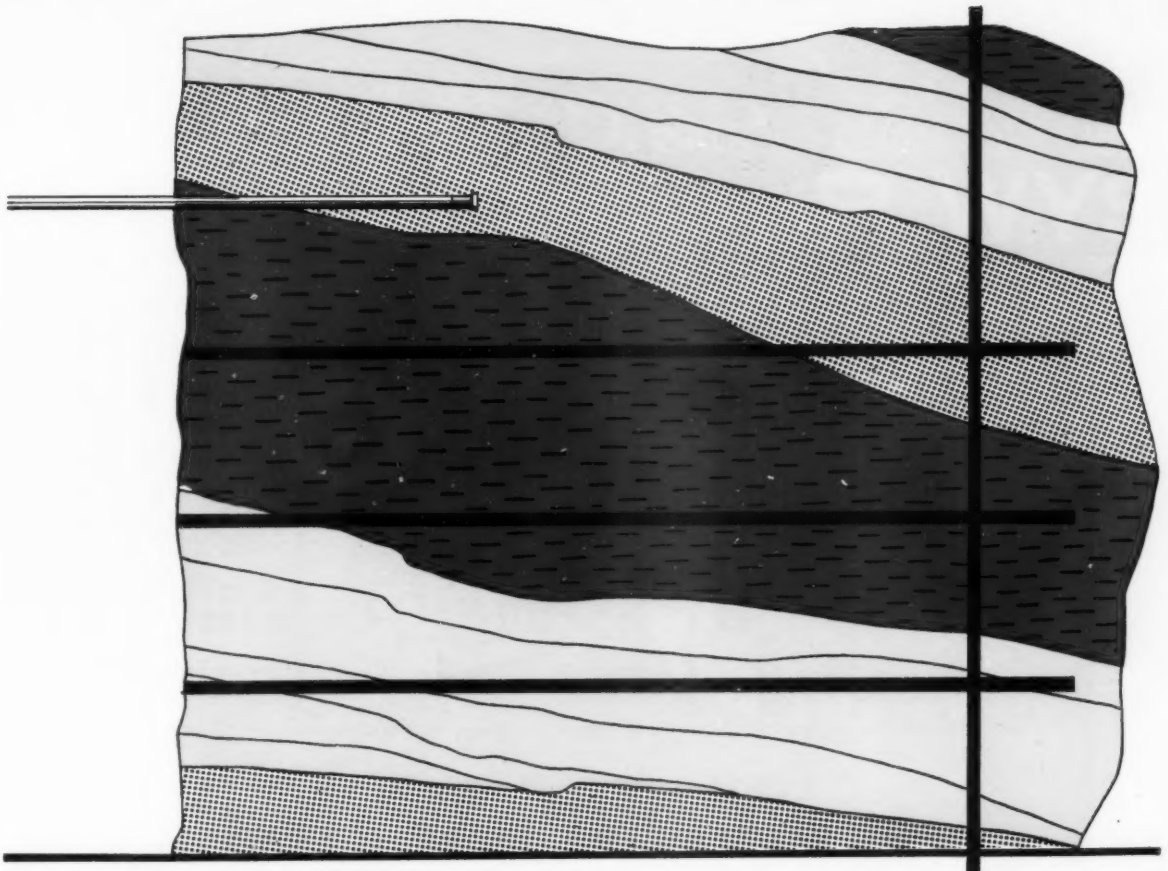
**SERVING DESIGN & ENGINEERING NEEDS WORLDWIDE WITH**

- Reconnaissance and Surveys
- Preliminary Analyses and Evaluation
- Estimates, Financing Plans and Project Recommendations
- Design Drawings and Construction Specifications
- Analysis of Bids and Bid Recommendations
- Detailed Construction Drawings
- General Engineering Supervision
- Final Reports and Record Drawings

**INTERNATIONAL ENGINEERING COMPANY, INC.**

74 New Montgomery Street • San Francisco, California, U. S. A.
A subsidiary of Morrison-Knudsen Company, Inc.

*For a complimentary copy of our 16-page illustrated brochure, write to Dept. C-2.*



# Drill parallel holes at sustained high speed —with the improved Holbit

You'll cut drilling time and improve blasting efficiency with the Holbit. Made only by Holman — in a factory laid out especially for the purpose — the Holbit is tungsten-carbide tipped and designed to drill straight, even-diameter holes at a fast, constant rate. Fewer drill rods and fewer steel changes are needed. And the amount of compressed air used by smaller steel drills is greatly reduced.

Single chisel and cross types are made in many sizes and in grades of carbide to suit every sort of rock. They can be used with any type, size and make of drill.

Holbits can save you a mint of money. Fast drilling, fewer steel changes, less transport, less compressed air. And improved blasting.

What are you waiting for?

**Holman** PNEUMATIC EQUIPMENT

**pays . . . with its life**

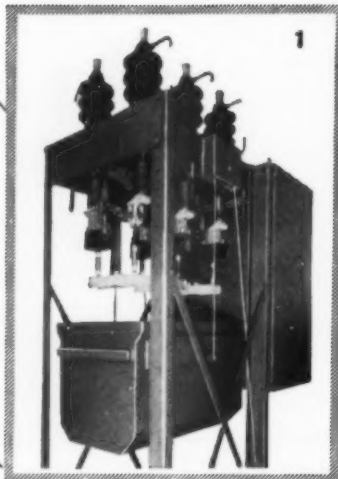
HOLMAN BROS. LTD., CAMBORNE, ENGLAND

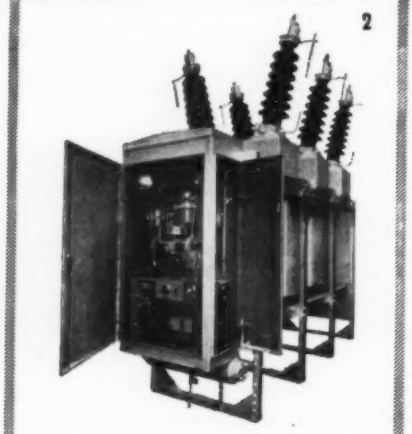
*The Holman Organisation is world-wide. It includes the Climax Rock Drill & Engineering Works Ltd., and has agents, branches and technical representatives throughout the United Kingdom and in 84 other countries.*

*Telephone: Camborne 2275 (10 lines). Telegrams: Airdrill, Telex, Camborne. London Office: 44 Brook Street, W.1. Telephone: Hyde Park 9444*

HJ22

G.E.C.


1

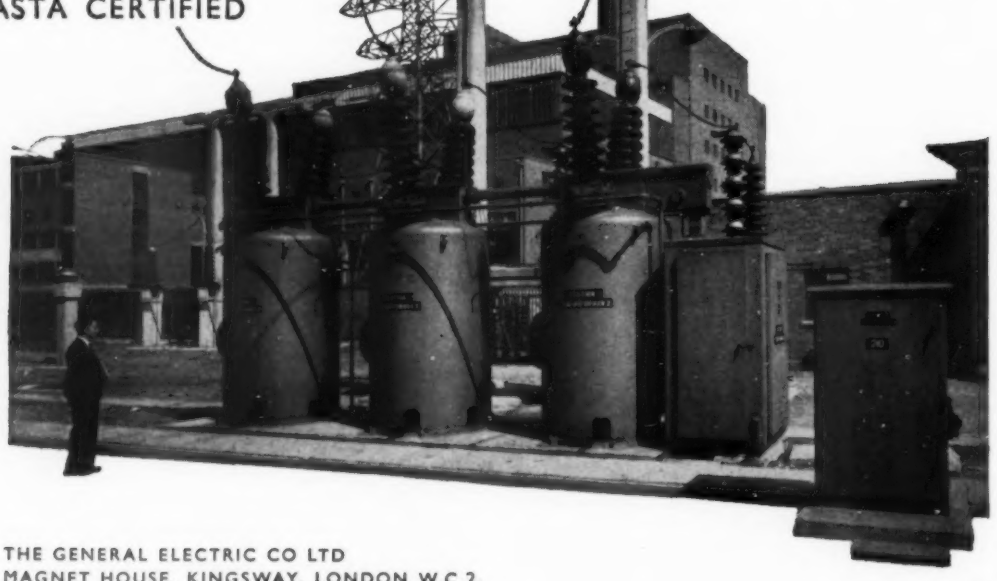

2

1. 11 kV to 15 kV up to 600 MVA at 15 kV.
2. 33 kV to 66 kV up to 1,500 MVA at 66 kV. Available also from stock in single tank form for 33 kV, up to 750 MVA.
3. 110 kV to 132 kV up to 5,000 MVA at 132 kV.

*Ask for Technical Description No. 389.*

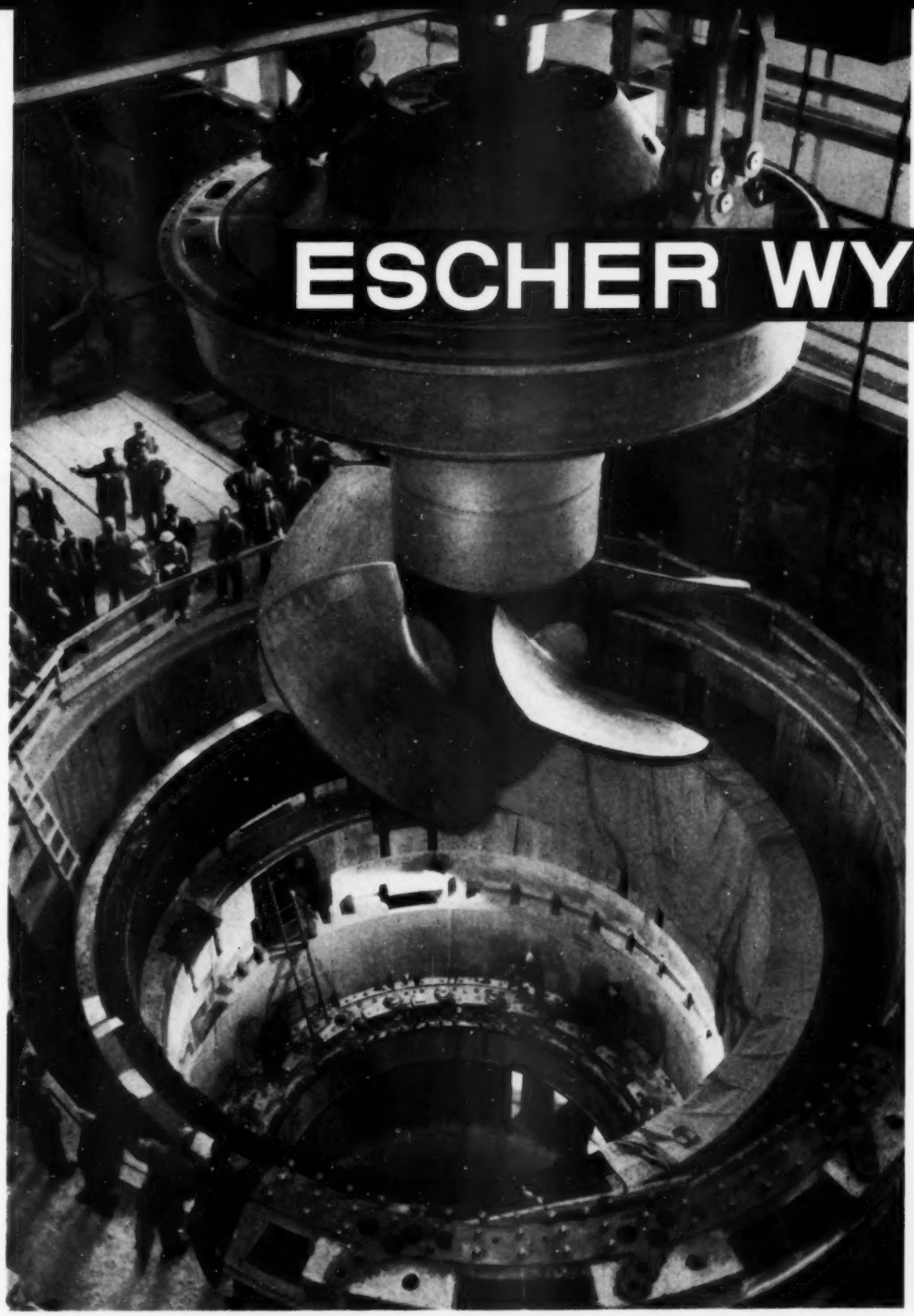
# Outdoor oil circuit breakers

ASTA CERTIFIED


3

THE GENERAL ELECTRIC CO LTD
MAGNET HOUSE, KINGSWAY, LONDON W.C.2.

227




Lowering the runner wheel into one of the Escher Wyss Kaplan turbines at the Rheinau Power Station (Switzerland)

**For this installation we have delivered 2 Kaplan turbines with a total output of 46,000 h.p.**

---

**Escher Wyss further specialize in Francis and Impulse turbines and in Storage Pumps up to the largest outputs and heads, as also in sluice gates, penstocks and tunnel linings.**

**ESCHER WYSS LTD., ZURICH (SWITZERLAND)**

**440 B.H.P. UNDER 114 FT. HEAD - - -**

## - - - AGAIN AN ARMFIELD TURBINE

*Illustration reproduced by kind permission of the North of Scotland Hydro-Electric Board. Consulting Engineers, Messrs. Kennedy & Donkin. Induction Generator, Messrs. Bruce Peebles & Co. Limited.*

THE ARMFIELD HYDRAULIC ENGINEERING CO. LTD.

RINGWOOD, HAMPSHIRE, ENGLAND. *Phone Ringwood 760. Grams Hydraulics, Ringwood*

as one contractor to another—

the best in the field

Ingersoll-Rand

air equipment

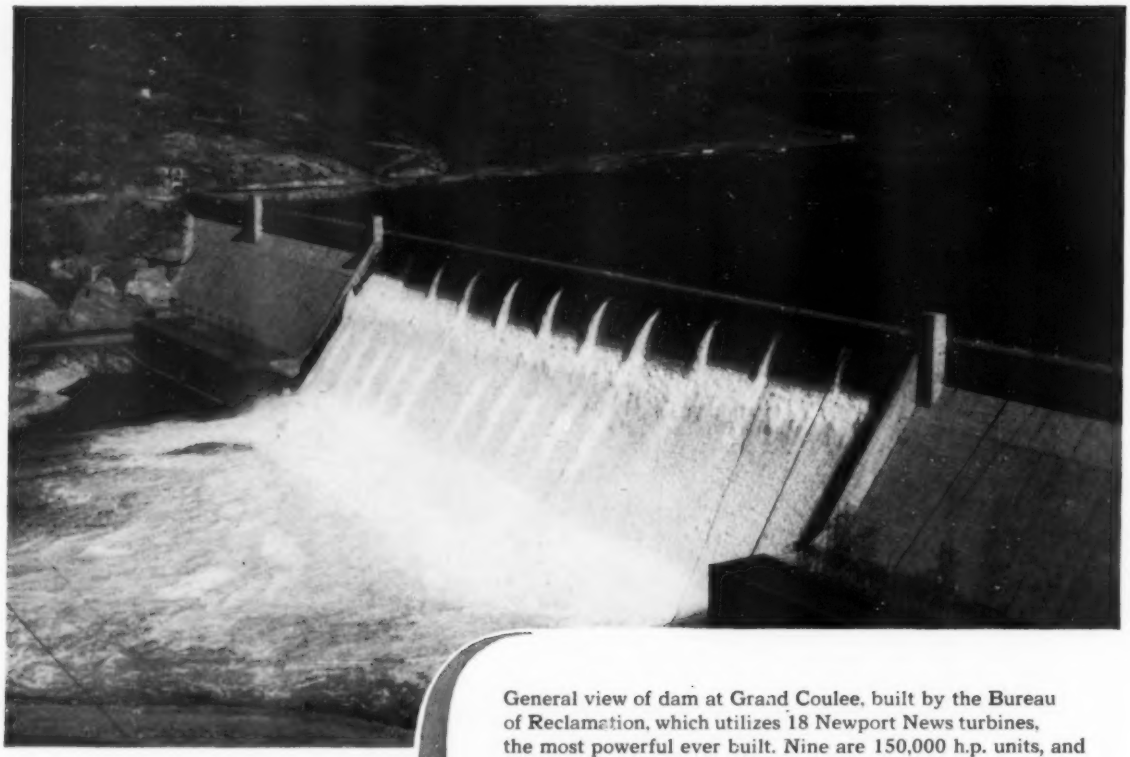
BRITISH MADE

*For full details and literature write to*

INGERSOLL-RAND CO LTD 165 QUEEN VICTORIA ST LONDON EC4 TEL CEN 5681

SCOTTISH OFFICE 20 RENFREW ST GLASGOW C2 TEL DOUGLAS 1233 GRAMS INGERSOLL GLASGOW

F627



General view of dam at Grand Coulee, built by the Bureau of Reclamation, which utilizes 18 Newport News turbines, the most powerful ever built. Nine are 150,000 h.p. units, and the other nine are rated at 165,000 h.p. each.

# Specialists ... in building Water Power Equipment

### Typical Users of Newport News Equipment

| PLANT | LOCATION |
|---|---|
| Boone | Tennessee |
| Buchanan | Texas |
| Caonillas | Puerto Rico |
| Chief Joseph | Washington |
| Clark Hill | South Carolina |
| Deer Lake | Newfoundland |
| Folsom | California |
| Fort Patrick Henry | Tennessee |
| Hiwassee | Tennessee |
| Hoover | Nevada |
| J. H. Kerr | Virginia |
| Jim Woodruff | Florida |
| Lower Salmon | Idaho |
| Norris | Tennessee |
| Rock Creek | California |
| Santee-Cooper | South Carolina |
| C. J. Strike | Idaho |
| Whitney | Texas |
| Wilson | Alabama |

Turbines designed and built for the world's largest development at Grand Coulee... and for other hydroelectric installations in America and various parts of the world... bespeak the skill and facilities offered by Newport News.

This trained organization has filled hydroelectric turbine contracts with an aggregate rated output of 7,000,000 horsepower.

Other equipment designed and built by Newport News includes penstocks, pressure regulators, valves, pumps, gates and rack rakes. Upon request, a copy of our illustrated booklet entitled "WATER POWER EQUIPMENT" will be sent to you.

**Newport News**
**SHIPBUILDING AND DRY DOCK COMPANY**
*Newport News, Virginia*

# Water has its uses . . .

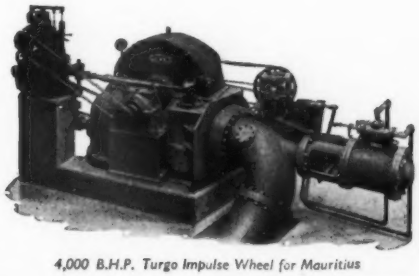
*SALMON Bred and born in the upper reaches of many of our rivers, the migratory Salmo salar later seeks the sea, to live and flourish until it returns at last to breed. It makes its way up-river, covering long distances in very short time, fighting swift currents and small waterfalls, often to reach the very place where it was hatched some years previously.*

The salmon fights its way up-stream against the currents that provide one of man's chief sources of power.

Wherever there is falling water a water turbine can be installed — the simplest and most reliable form of prime mover — no fuel bills, long life, little maintenance and requiring only unskilled attention.

GILKES are specialists in the field of small hydro-electric units; we can supply installations to operate on any head from 3 feet to 5,000 feet (or 1 metre to 1500 metres) and to develop any output up to 1,000 kilowatts on low heads or 10,000 kilowatts on the higher heads.

If you wish to make the fullest and most economic use of your potential water power, let GILKES advise you.



*4,000 B.H.P. Turgo Impulse Wheel for Mauritius*

## GILBERT GILKES & GORDON LTD

WATER TURBINE & PUMP MANUFACTURERS

KENDAL Telephone: Kendal 28 ENGLAND

G77

London Office: CRAVEN HOUSE, KINGSWAY, LONDON W.C.2. Telephone: HOLBORN 3231

COURTESY OF NORTH OF SCOTLAND HYDRO-ELECTRIC AUTHORITY AND MESSRS. TAYLOR WOODROW CONSTRUCTION LTD.

# ADAPTABILITY OF BAILEY BRIDGE UNITS

COURTESY OF RIXBURGH HYDRO-ELECTRIC AUTHORITY, NEW ZEALAND.

COURTESY OF THE MERSEY RIVER BOARD, CHESHIRE.

COURTESY OF STATE OF VERMONT HIGHWAYS DEPARTMENT, U.S.A.

COURTESY OF MESSRS. DEMOLITION AND CONSTRUCTION CO. LTD.

**There is no limit to the number of structures that can be built with Bailey Bridge Units—All types of Bridges, falsework, scaffolding, piers, buildings, gantries, runways etc.—in fact new components are constantly being designed to meet the requirements of civil engineers all over the world.**

**Very often it is possible to economise on known standard constructions, and we strongly recommend you to submit problems to our engineers so that the most economical solution can be employed.**

**We are interested in your particular problem, and are prepared to fabricate bridges and structures to your own individual designs.**

**THOS. STOREY (Engineers) LTD.**

WORLD LICENSEES FOR THE MANUFACTURE & SALE OF BAILEY BRIDGING

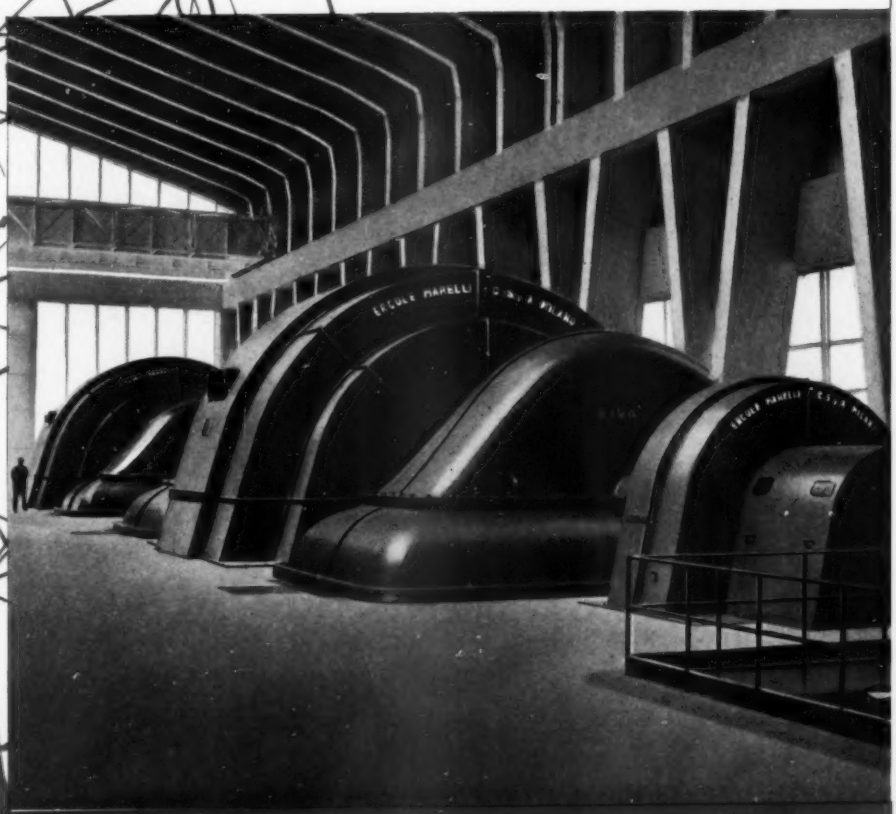
STOCKPORT & LONDON ENGLAND

ENQUIRIES TO LONDON SALES OFFICE · 6 VICTORIA STREET · WESTMINSTER SW1

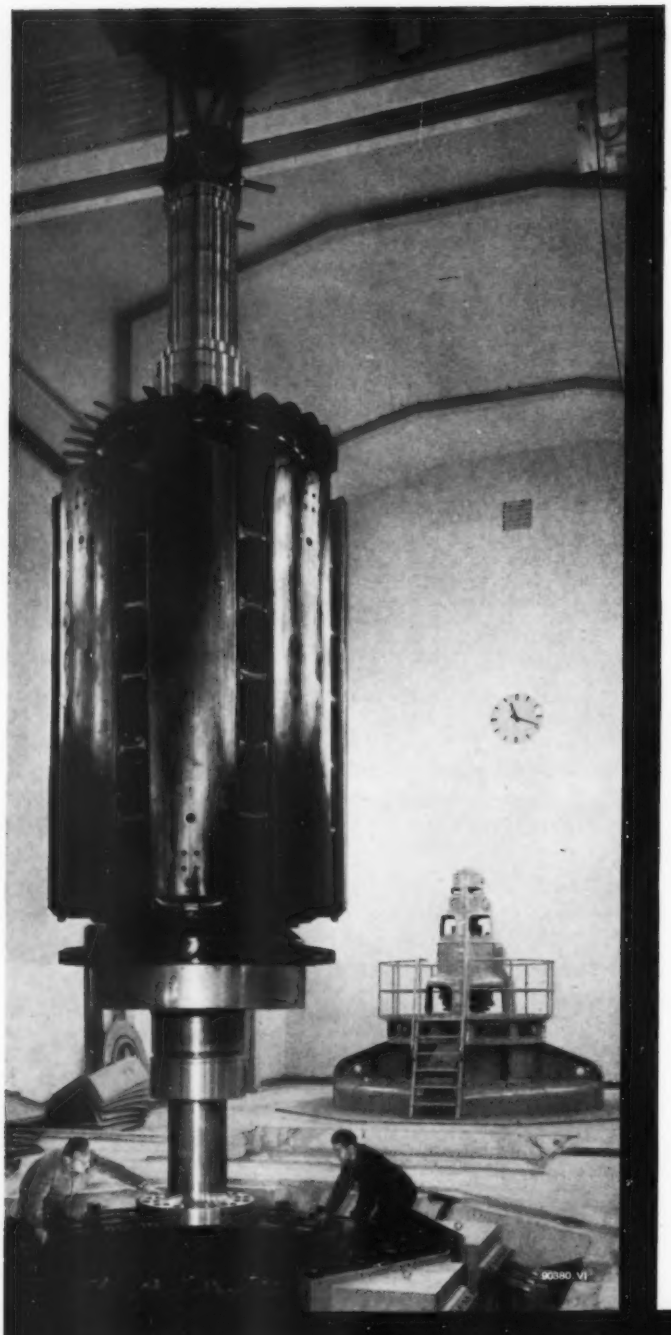
TELEPHONE: ABBEY 7391-2 TELEGRAM: MICROFAB SOWEST LONDON CABLES: MICROFAB LONDON

# Marelli

Soc. Idroelettrica Alto Chiese Cimego Hydro - Electric Power Station. Two 110,000 kVA horizontal shaft alternators 13,800 V. — 50 cycles — 300 r.p.m. — $PD^2$ 4,400 $tm^2$ — each weighing 650 tons — coupled to 150,000 H.P. Pelton turbine.



**ERCOLE MARELLI & C. - S. p. A.**
**MILANO**



## Brown Boveri leaders in the design of high-speed salient-pole waterwheel generators

**Lowering the rotor into the second alternator at the Fionnay Power Plant in Switzerland, owned by the Forces Motrices de Mauvoisin, S.A., Sion, where three generators rated 60 MVA, 0.8 p.f., 750 r.p.m., 10.5 kV, 50 c/s are being installed.**

Some high-speed waterwheel generators at present under construction, or recently installed:

| No. of Units | Output kVA | Shaft | Speed r.p.m. | Power Station | Country |
|---|---|---|---|---|---|
| 1 | 23 000* | V | 1 000 | Oberaar | Switzerland |
| 2 | 20 000 | H | 1 000 | Ernen | Switzerland |
| 3 | 60 000 | V | 750 | Fionnay | Switzerland |
| 3 | 29 000 | H | 750 | Motec | Switzerland |
| 1 | 30 000 | V | 750 | Piottino | Switzerland |
| 3 | 57 500 | V | 720/600 | Tingambato | Mexico |
| 1 | 60 000 | V | 600 | Paradela | Portugal |
| 2 | 45 000 | V | 600 | Hemsil II | Norway |
| 3 | 17 650 | V | 600 | Neriamangalam | India |

* Synchronous motor

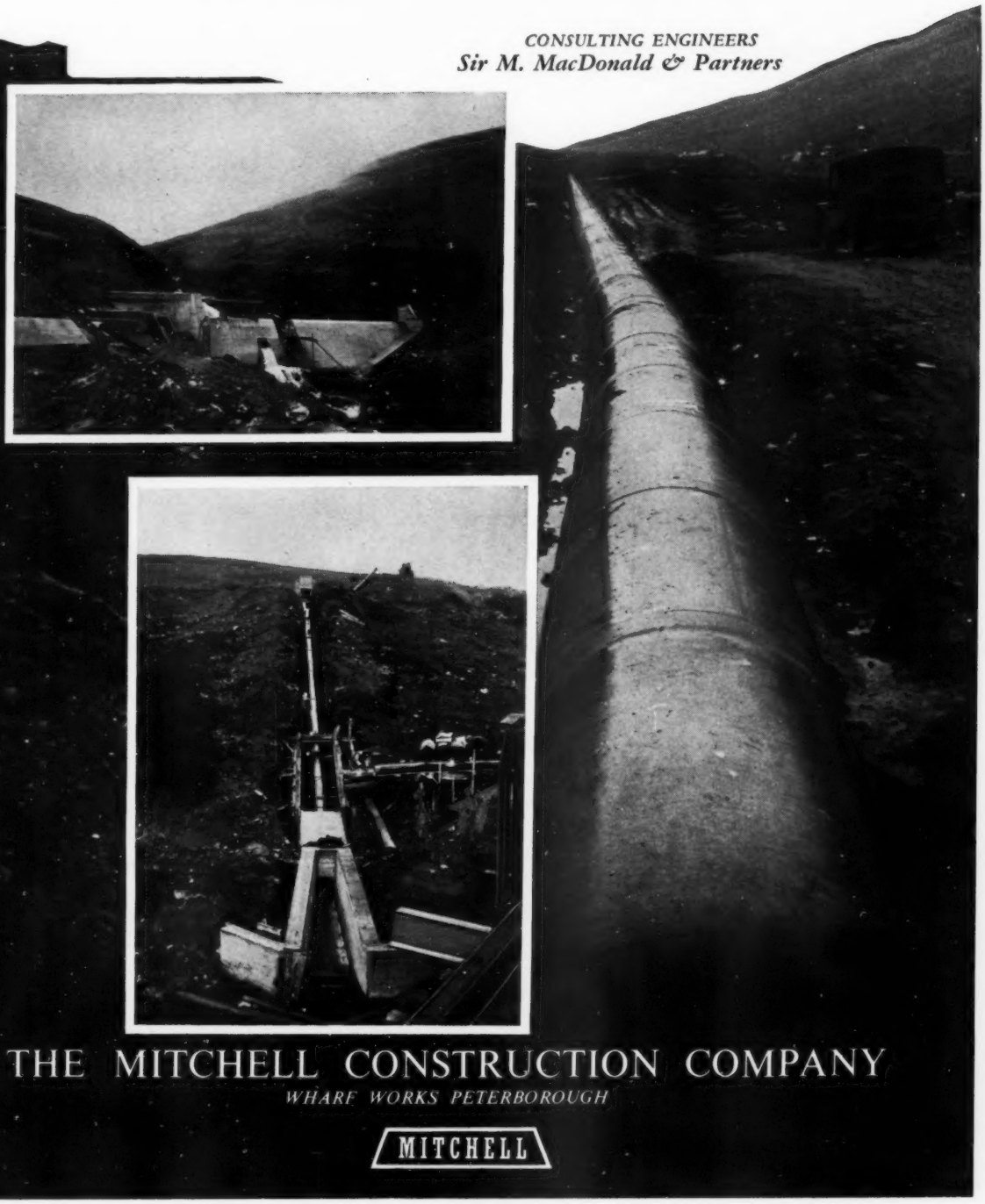
BROWN BOVERI

**BROWN, BOVERI & CO., LTD.**
**BADEN**
**SWITZERLAND**

# *Aqueducts*

**Pipe aqueducts totalling 5 miles in length and up to 60" in diameter have been laid by The Mitchell Construction Company on the St. Fillans section of the North of Scotland Hydro-Electric Board's Breadalbane Scheme. The aqueducts form part of the main civil engineering contract entrusted to the Company. The contract also includes nineteen miles of tunnelling in addition to generating stations and numerous intake works.**

*CONSULTING ENGINEERS*
***Sir M. MacDonald & Partners***



THE MITCHELL CONSTRUCTION COMPANY
*WHARF WORKS PETERBOROUGH*

MITCHELL

# PENSTOCKS
# WATER GATES
# HYDROELECTRIC
# EQUIPMENT

**CAP DE LONG:** Self-hooped penstock for the Pragnères Power Station, in the Pyrénées.
Head 1,252 metres, Flow 14,6 cu.m./sec.
Diameter 2.25 to 1.60 metres, Power 200,000 H.P.

**PASSY:** Penstock bridge over the River Arve, in the French Alps.
Span 72 metres, Diameter 3 metres.

**ETABTS. BOUCHAYER & VIALLET**
**SOCIETE DAUPHINOISE d'ÉTUDES & de MONTAGES**
**GRENOBLE - FRANCE**

# RAPIER

# WATER CONTROL GATES

**MANCHESTER SHIP CANAL**

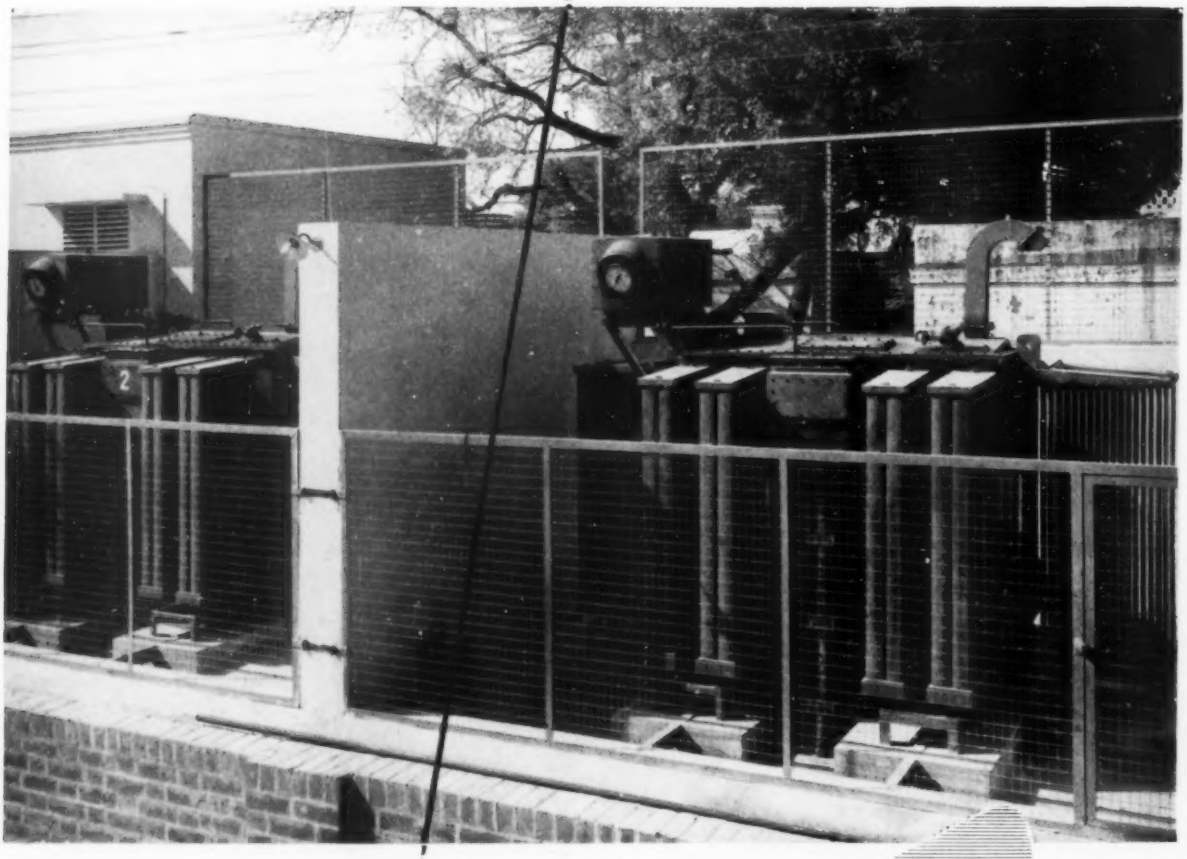
Ten wheel gates 30 ft. span by 17 ft. 6 in. deep

**HYDRO-ELECTRIC · IRRIGATION**
**FLOOD CONTROL · WATER SUPPLY**
**LOCKS and DOCKS**

***Contracts carried out in all parts of the world***

## RANSOMES & RAPIER LTD. IPSWICH ENGLAND

*Constructed by* / *Careful Craftsmen*



Y.E.T

*Transformers in India*

10,000 k.V.A. UNITS

AT DELHI 'B' POWER STATION

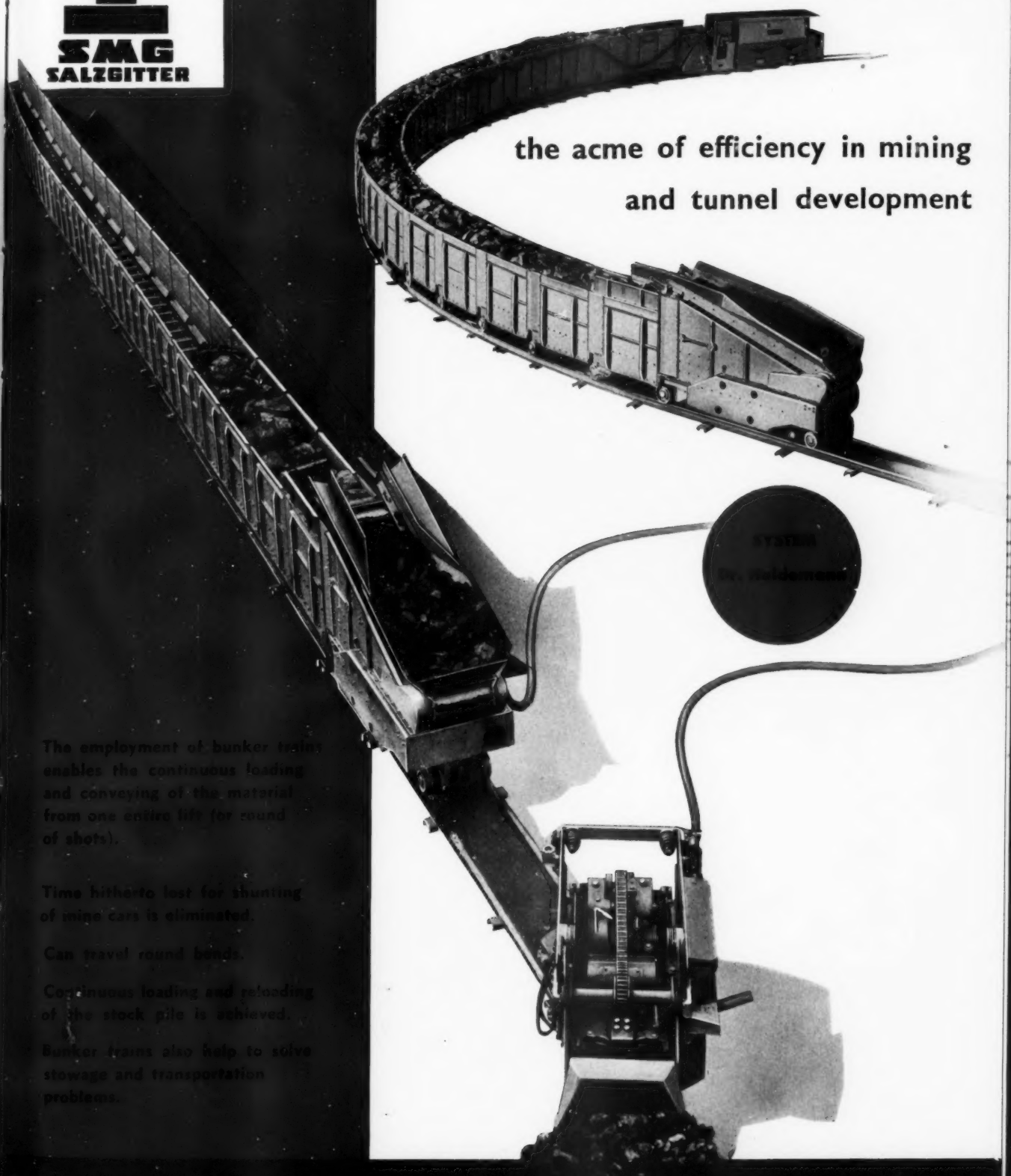
**YORKSHIRE ELECTRIC TRANSFORMER CO. LTD.**
**THORNHILL, DEWSBURY**
**YORKSHIRE**
Telephone : Dewsbury 1691/2

**YORKSHIRE ELECTRIC TRANSFORMER CO. LTD.**

SMG
SALZGITTER

# SALZGITTER
## BUNKER TRAIN BZ 35

**the acme of efficiency in mining and tunnel development**



The employment of bunker trains enables the continuous loading and conveying of the material from one entire lift (or round of shots).

Time hitherto lost for shunting of mine cars is eliminated.

Can travel round bends.

Continuous loading and reloading of the stock pile is achieved.

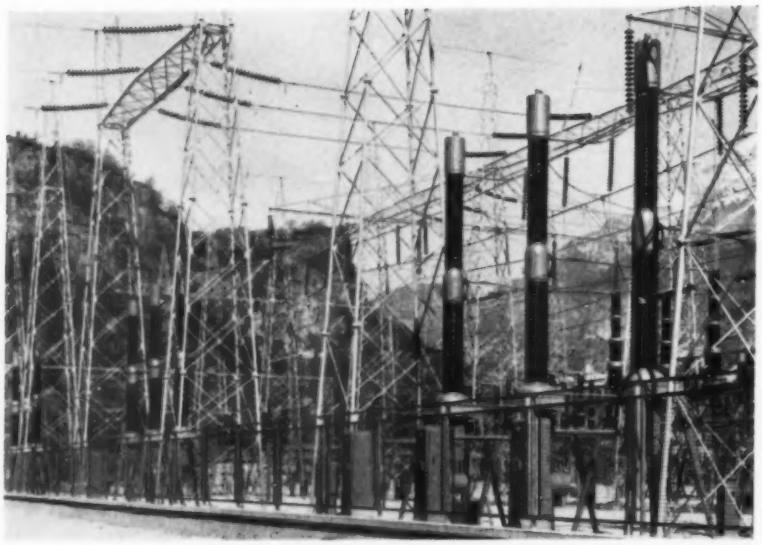
Bunker trains also help to solve stowage and transportation problems.

SALZGITTER MASCHINEN AKTIENGESELLSCHAFT

SALZGITTER-BAD

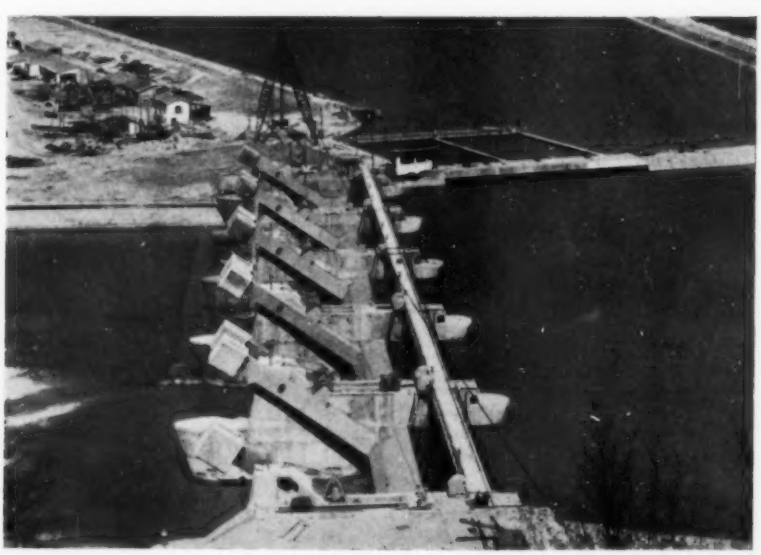
Phone 441 Salzgitter-Bad  Telex samagsalzgitter 0953 805  Telegrams Samag

OFFICINE ELETTRO MECCANICHE GALILEO
DI BATTAGLIA TERME S.p.A.



circuit breakers, isolating switches and measuring transformers for 220 kV. Somplago Power station

Officine Elettromeccaniche Galileo build electrical equipment for medium, high and ultra-high voltage, travelling cranes, gates of any type, racks, rack rakes and any other metallic frame for hydro-electric plants



barrage on the Volturno river five automatic sector gates 25 mt. wide; 375 mt. high

For offers and details, please enquire to: Officine Elettromeccaniche Galileo, Servizio Commercio Estero, via Larga, 26, Milano (Italy) — Phone: 877895. Grams: Elettroga, Milano

Lake Oberaar, 7,550 ft. above sea level, in the Bernese Oberland, Switzerland

# SULZER

**are supplying the four largest**

## High-Lift Storage Pumps

**in the world for the Ffestiniog Hydro-Electric Power Scheme of the Central Electricity Authority in North Wales**

Working data of each pump:

| | |
|---|---|
| Discharge | 278,520 g.p.m. |
| Head | 1,000 ft. |
| Speed | 428 r.p.m. |
| Input, mean | 94,600 H.P. |
| max. | 110,000 H.P. |

**The following high-lift storage pumps for hydro-electric power schemes are also in hand:**

**Lünersee (Austria)**
49,250 g.p.m., 3,182 ft., 54,750 H.P.

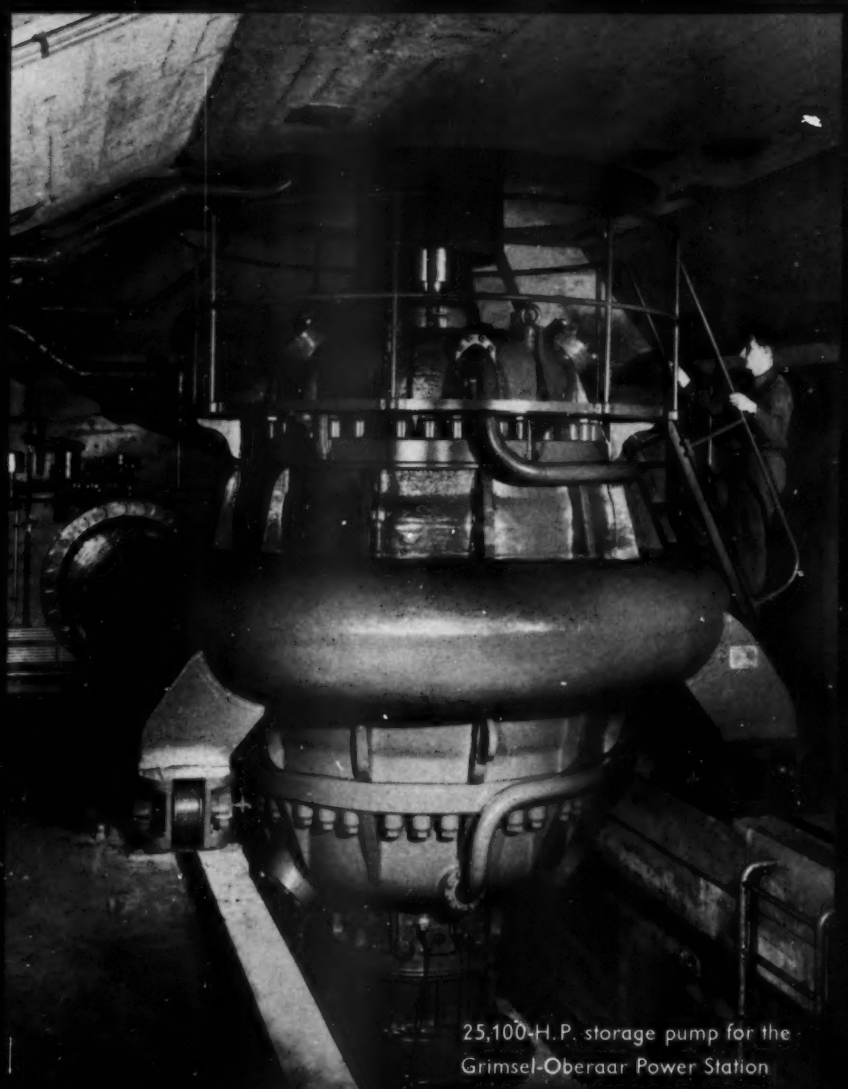
**Motec (Switzerland)**
43,050 g.p.m., 2,060 ft., 30,400 H.P.

---

**Sulzer Brothers Limited,**
**Winterthur, Switzerland**

**Sulzer Bros. (London) Ltd.,**
**31, Bedford Square, London, W.C.1**

(Incorporating:
Hathorn, Davey & Company Ltd.)



25,100-H.P. storage pump for the Grimsel-Oberaar Power Station

F
FERRANTI

# 330,000 volts

## transformers for Kariba

The contract awarded to Ferranti Ltd. by the Federal Power Board for the great Kariba Hydro-Electric Scheme on the Zambesi River covers two 120,000 kVA 330/234 kV 3-phase auto transformers with separate boosters; eight 60,000 kVA 330/88 kV 3-phase double-wound transformers; and two 60,000 kVA 330/33 kV 3-phase double-wound transformers. All the transformers will be provided with on-load tap changing gear. The placing of this large and important overseas transformer contract emphasises the world-wide confidence in Ferranti Ltd. as builders of fine transformers.

**FERRANTI LTD · HOLLINWOOD · LANCS**
London Office: KERN HOUSE · 36 KINGSWAY · W.C.2

**FERRANTI**

FT 208/2

OERLIKON
Rotor ready for mounting on to the third Oerlikon alternator of 40,000 kVA, 300 r.p.m. in the Handeck II Power station, Switzerland
© OERLIKON 63370

**Oerlikon Engineering Company • Zurich 50 (Switzerland)**

A. O. SMITH MULTI-LAYER PENSTOCKS

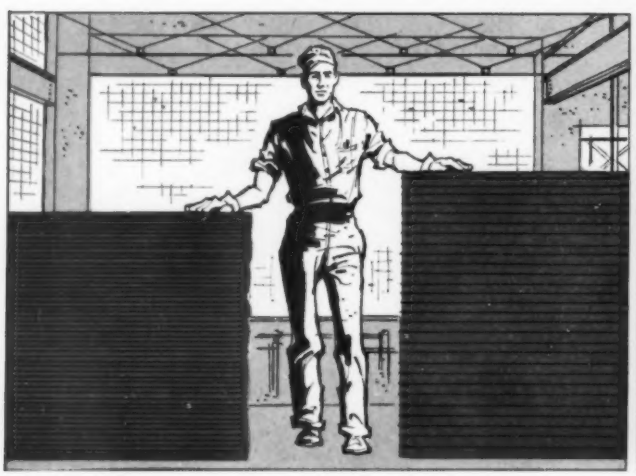
# How built-up walls cut down costs

Savings start—then grow, the moment A. O. Smith MULTI-LAYER penstocks are installed. Ideally suited for high hydrostatic pressures, MULTI-LAYER's remarkable strength results from the *number* and *type* of built-up thin steel plates required to handle your job.

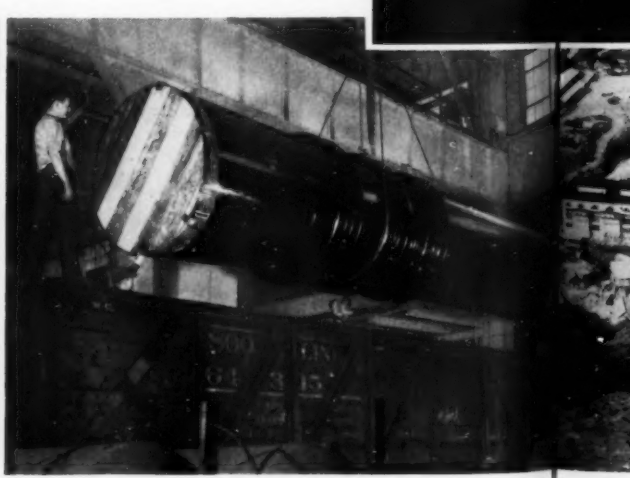
Critical material control such as this offers optimum safety and strength at lowest possible cost. Yet there's no practical limitation to the pressures that can be handled.

A complete selection of MULTI-LAYER sizes are available . . . small-diameter, thin-wall up to 30" . . . larger diameters made to order including "wyes," "bends," and other "specials."

For aid in solving penstock problems, backed by unlimited research and production facilities, write A. O. Smith International S. A., Administrative Offices: P. O. Box 331, Milwaukee 1, Wis., U. S. A.



**MULTI-LAYER saves up to 15% in amount of steel required** for conventional *thick* plate, single wall penstocks of the same diameter. MULTI-LAYER *saves tonnage*. Layers of thin, high-tensile strength steel plate are progressively wrapped, tightened and welded around the core.



**MULTI-LAYER saves in freight and cargo costs.** A. O. Smith MULTI-LAYER penstocks weigh less . . . shipping costs are substantially cut. Especially important when jobs are located in remote areas. Handling and erection are faster, easier at the job site.

Manufacture of MULTI-LAYER pipe section. This modern A. O. Smith construction results in lighter, safer and more easily welded high-head penstock sections, as compared to ordinary single wall construction.

**MULTI-LAYER saves by eliminating costly stress-relieving of welds** in the field. Residual stresses in welds are negligible. MULTI-LAYER requires no bothersome, time-consuming handling of sections into and out of stress-relieving furnaces.

*Through research* A.O. Smith *... a better way*

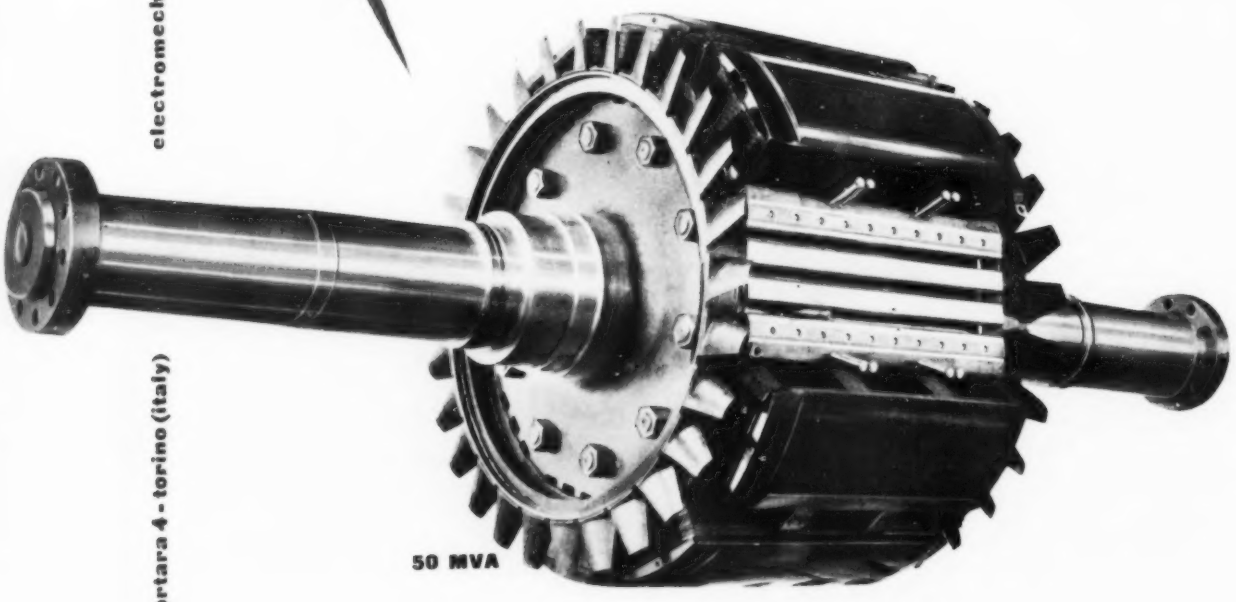
# A.O.Smith

**INTERNATIONAL S. A.**

Administrative Offices:
P. O. Box 331,
Milwaukee 1, Wisconsin, U.S.A.

# savigliano

electromechanical construction



50 MVA

società nazionale delle officine di savigliano - corso mortara 4 - torino (italy)

M·A·N

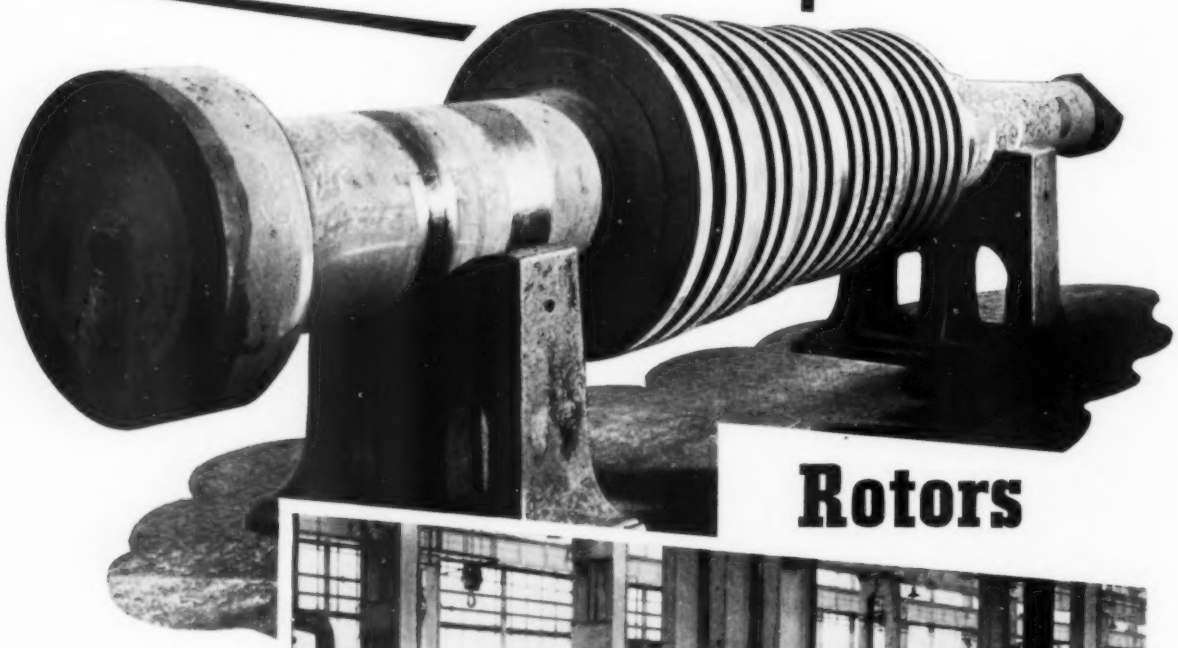
# HYDRAULIC LABORATORY

In the planning and constructing of hydraulic steel structures it is important to find the most economic and best shaping. For this, model tests are carried out with modern measuring appliances on weirs, locks, deep sluice gates and dry docks. This has enabled the M.A.N. hydraulic laboratory to guarantee the Client reliable advice for the past 50 years.

1356

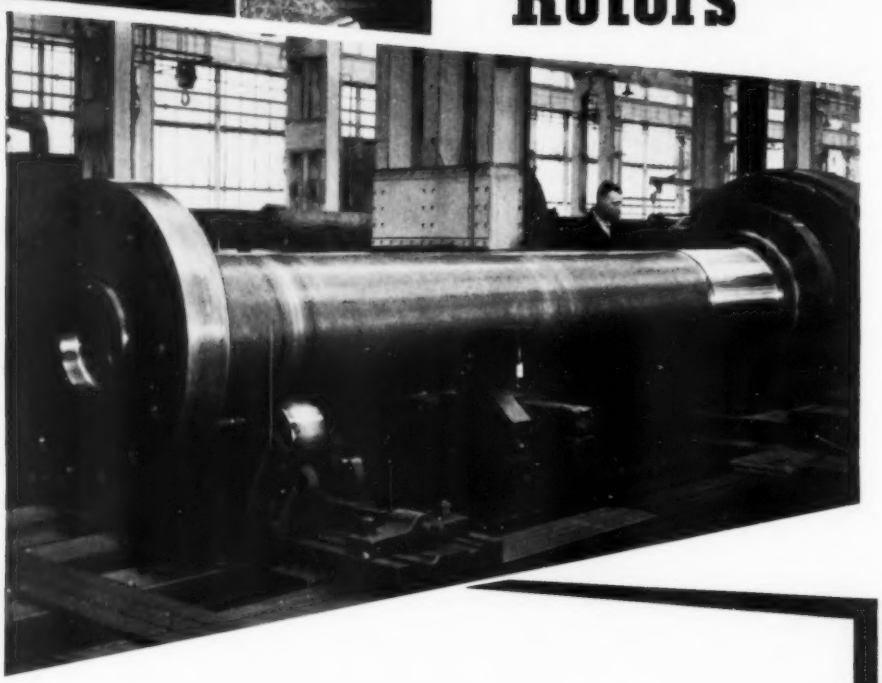
**MASCHINENFABRIK AUGSBURG-NÜRNBERG AG GUSTAVSBURG WORKS**
**GUSTAVSBURG/HESSEN (GERMANY) REPRESENTATIVES IN ALL COUNTRIES**

# Steel Forgings



Rotors

Turbine shafts

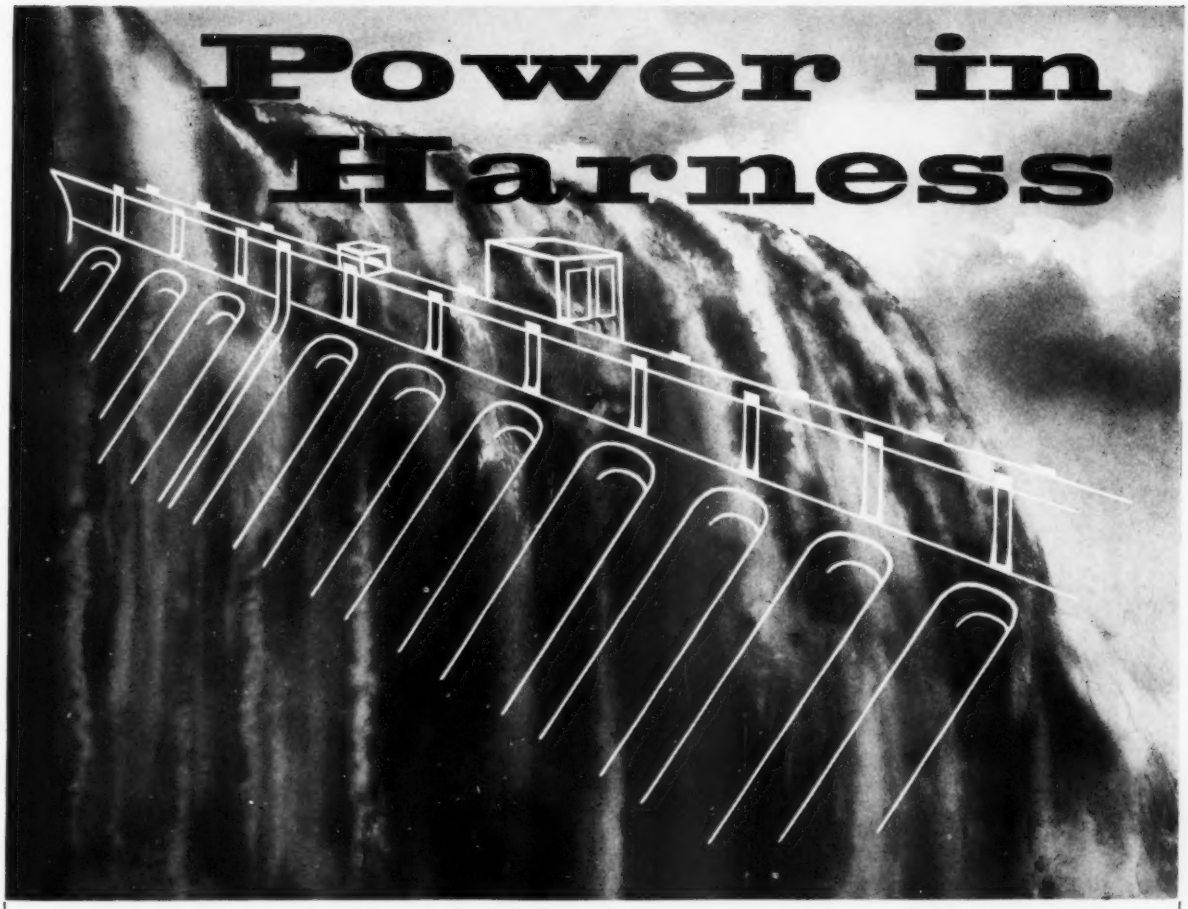


ESC

**ENGLISH STEEL FORGE AND ENGINEERING CORPORATION**
*Limited*

***River Don Works, Sheffield***

*A wholly owned subsidiary of English Steel Corporation Ltd.*




# BALFOUR BEATTY

## & CO. LIMITED

HYDRO-ELECTRIC PLANTS · DAMS · RESERVOIRS
WATER SUPPLY · SEWERAGE WORKS
TUNNELS · AQUEDUCTS · IRRIGATION

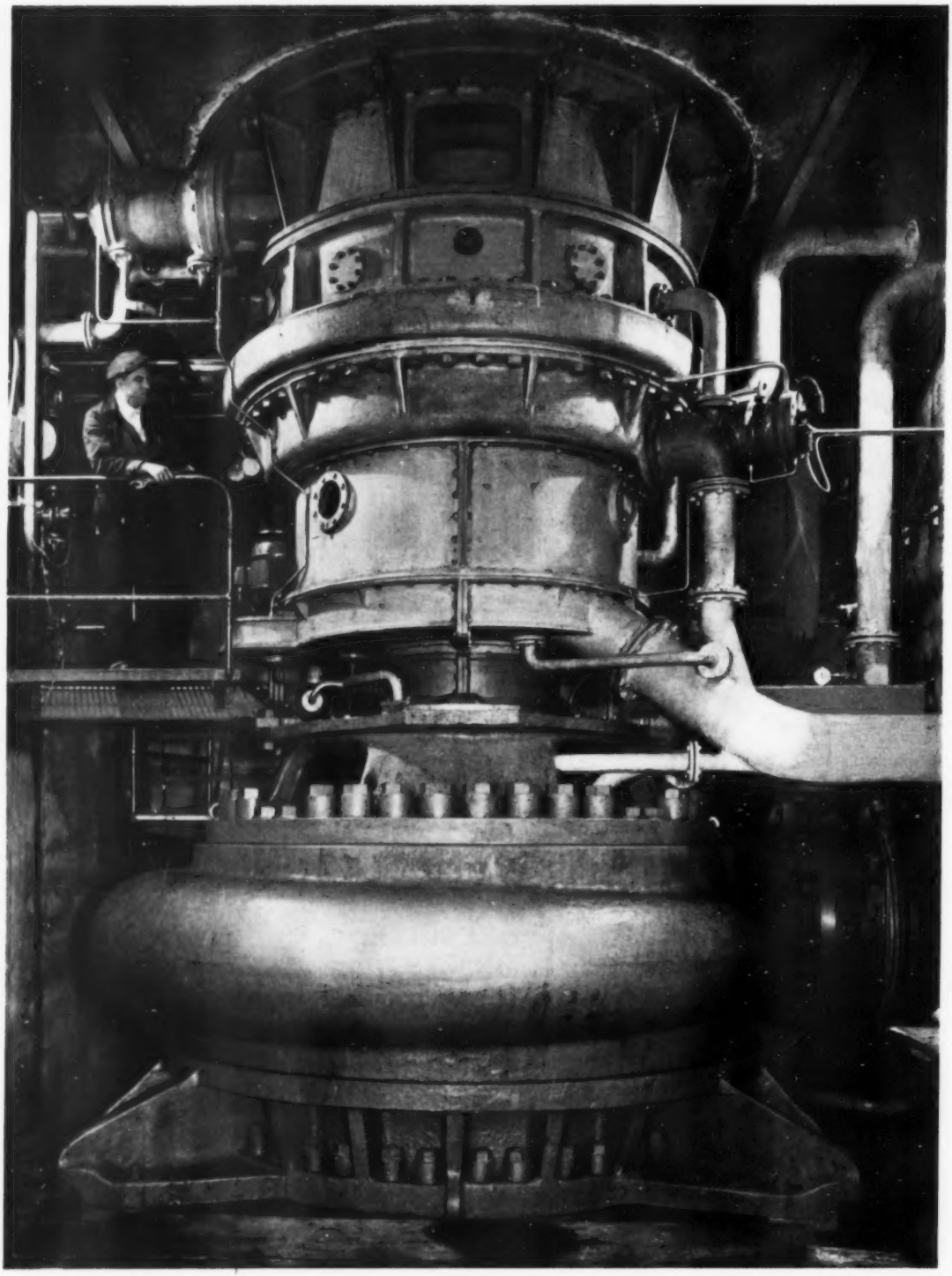
A COMPLETE ENGINEERING SERVICE FROM THE PRELIMINARY INVESTIGATION TO THE COMPLETION AND MANAGEMENT OF ANY PROJECT.

Head Office

66 QUEEN STREET · LONDON E.C.4

and at

EDINBURGH · TORONTO · BAGHDAD · NAIROBI



Within 25 seconds the torque-converter driven 59,000 h.p. pump, starting from rest, operates at full capacity. In the Lünersee Pumped Storage Station, on 2nd November, 1957, the first of the 2 all-Voith sets went into successful operation. Each set comprises a 4-jet 63,000 h.p. Voith Impulse Turbine, a 5-stage 59,000 h.p. Voith Storage Pump, and a Voith Torque Converter with sliding gear coupling which starts and runs the pump up to synchronous speed for coupling to the motor-generator. Voith Torque Converters equip also the other three sets of the Lünersee Pumped Storage Scheme.

**J. M. VOITH GMBH · HEIDENHEIM (BRENZ) · GERMANY**

**Established 1867 –**
It is these years
of finding out
that have made,
and still keep,

**TT**

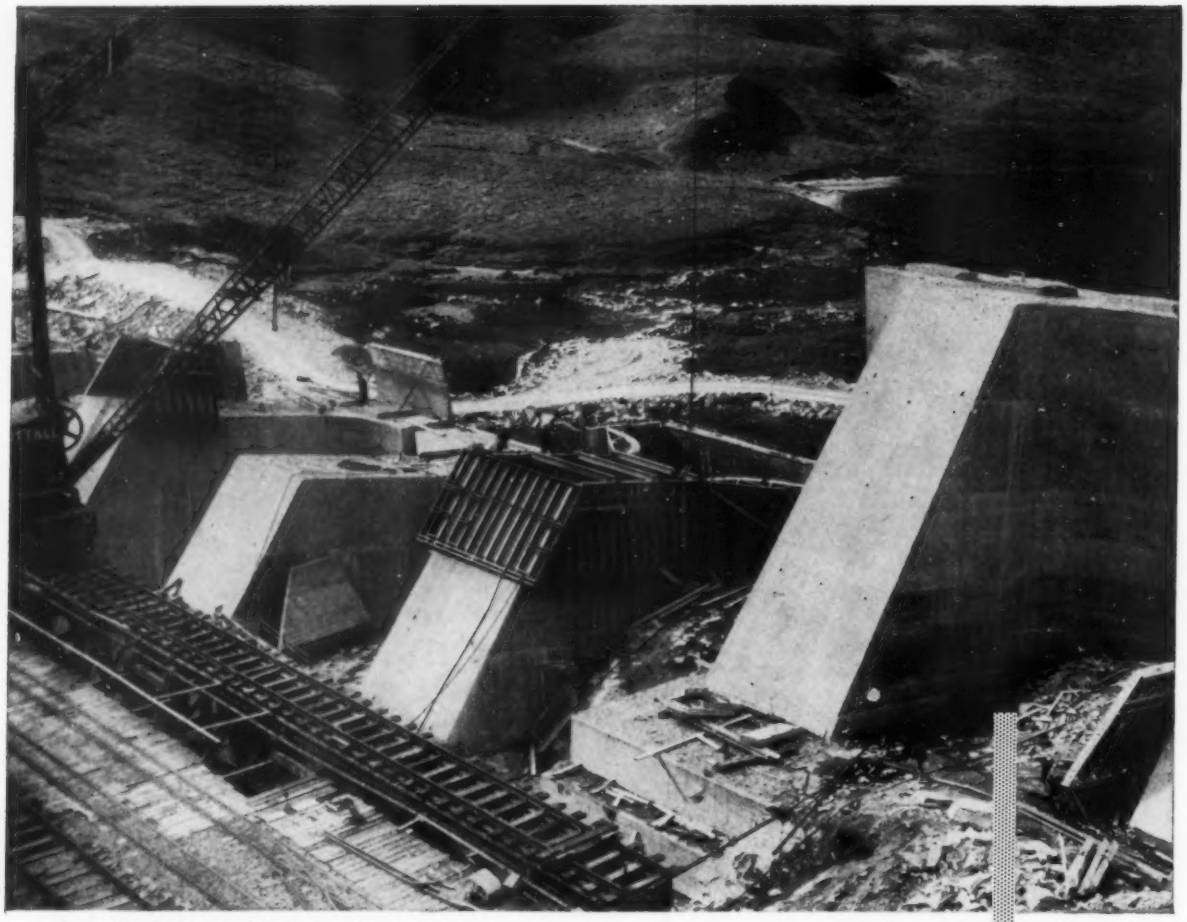
the foremost name
for

**PORCELAIN INSULATION**

*220 kV. Pressure Type Cable Sealing Ends incorporating T.T. porcelains installed at the Fontenay Research Station of Electricité de France 1948. Hydraulic routine test: 500 lb/sq. in. applied internally. Contractors: British Insulated Callender's Cables Ltd., and Enfield Cable Co. Ltd.*

*Consult* **TAYLOR TUNNICLIFF** *about*
**HIGH VOLTAGE PORCELAIN INSULATORS**

**TAYLOR TUNNICLIFF & CO. LTD.**, Head Office: EASTWOOD · HANLEY · STOKE-ON-TRENT · STAFFORDSHIRE
Telephone: Stoke-on-Trent 25272-5. · London Office: 125 HIGH HOLBORN, W.C.1. Telephone: Holborn 1951-2



*Authority: North of Scotland Hydro Electric Board*
*Consulting Engineers: James Williamson & Partners*

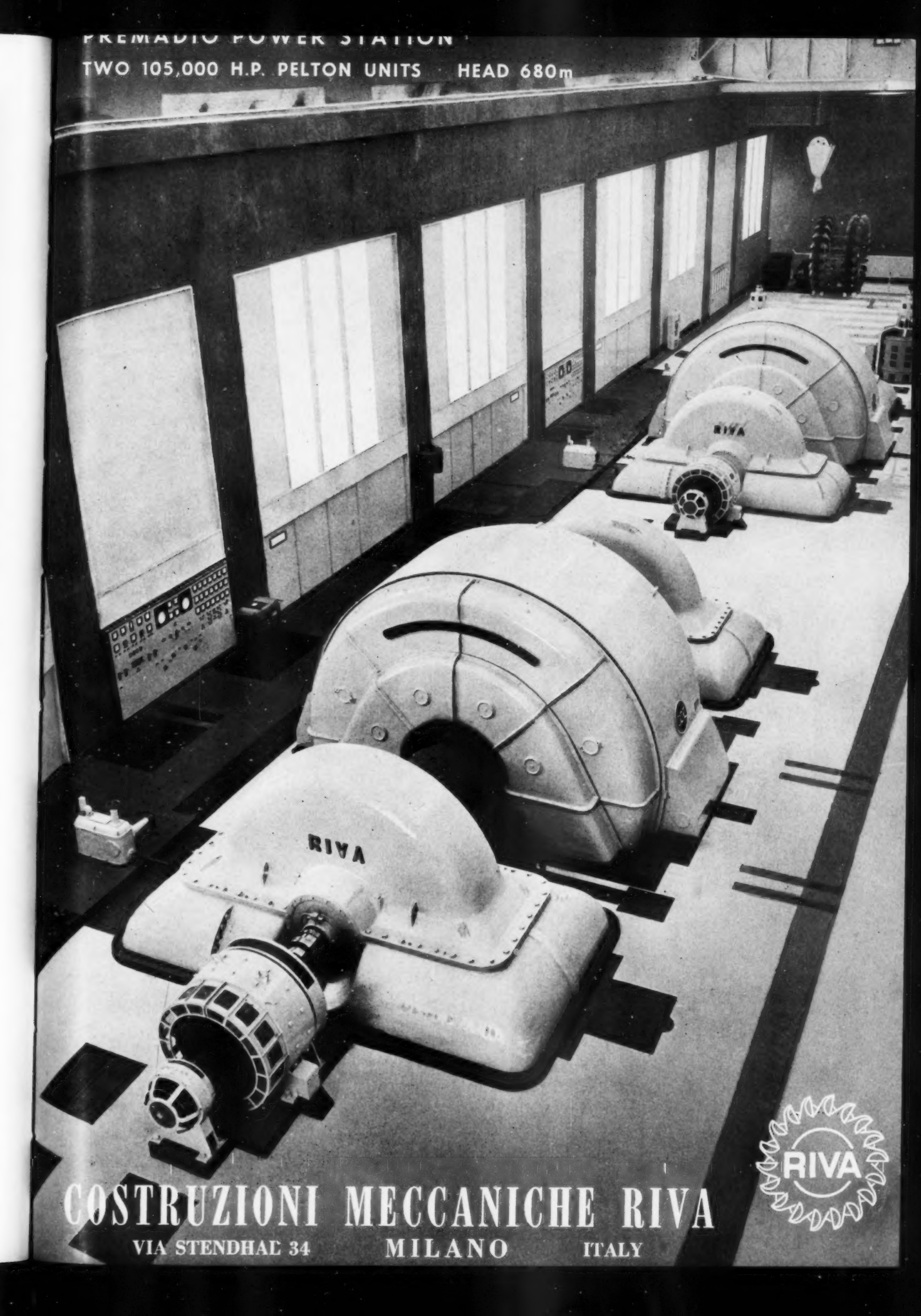
## THE GIORRA DAM

The 1,450 foot long and 100 foot high dam at the eastern end of Loch Giorra is an important part of the Killin Section of the North of Scotland Hydro-Electric Board's Breadalbane Power Scheme. Edmund Nuttall are the contractors for this work and the photograph shows an early stage in concreting on the buttresses of the Dam.

EDMUND NUTTALL

*CIVIL ENGINEERING CONTRACTORS*

EDMUND NUTTALL, SONS & CO. (LONDON) LTD. 22 GROSVENOR GARDENS, LONDON S.W.1. TELEPHONE: SLOANE 0036


PREMADIO POWER STATION
TWO 105,000 H.P. PELTON UNITS HEAD 680m
RIVA
RIVA
COSTRUZIONI MECCANICHE RIVA
VIA STENDHAL 34 MILANO ITALY
RIVA

# What's yours?

If it's a difficult non-ferrous casting—consult Birkett, Billington & Newton. Above is an example of what they can do. It is one of a pair of housings for the driving shaft of an independently sprung wheel. To withstand severe shocks and stresses it was cast in high tensile manganese bronze and then precision-machined.

Birkett, Billington & Newton have the facilities and knowledge to solve your non-ferrous casting problems—however difficult.

* * * * * * * * * *

**CASTINGS FROM A FEW OUNCES TO 10 TONS...**

*in phosphor-bronze, gun-metal, aluminium-bronze, manganese-bronze and light alloys. Precision-machined bushes and bearings. Specialists in high-tensile aluminium bronze castings, centrifugal-cast wheel blanks, and chill-cast rods and tubes.*

BIRSO TRADE MARK BN

***One of Britain's Largest* NON-FERROUS *Foundries***

**T. M. BIRKETT, BILLINGTON & NEWTON LTD**

HANLEY AND LONGPORT, STOKE-ON-TRENT

*Head Office: HANLEY, Phone: Stoke-on-Trent 22184 5 6 7. LONGPORT, Phone: Stoke-on-Trent 87303*

# NOHAB turbines-
# -one step ahead

NOHAB

NYDQVIST & HOLM AKTIEBOLAG

Trollhättan - Sweden

Cables: NOHAB - telex: 5264 - telephone: 18000

CARBON RING SEALS
type Fahlturbox for hydraulic turbines
GUSTAV HUHN STOCKHOLM Ö
SANDHAMNSGATAN 62 · TEL. 610124 · 610132 · 616611
HUHN
SPRINGER

# KMW

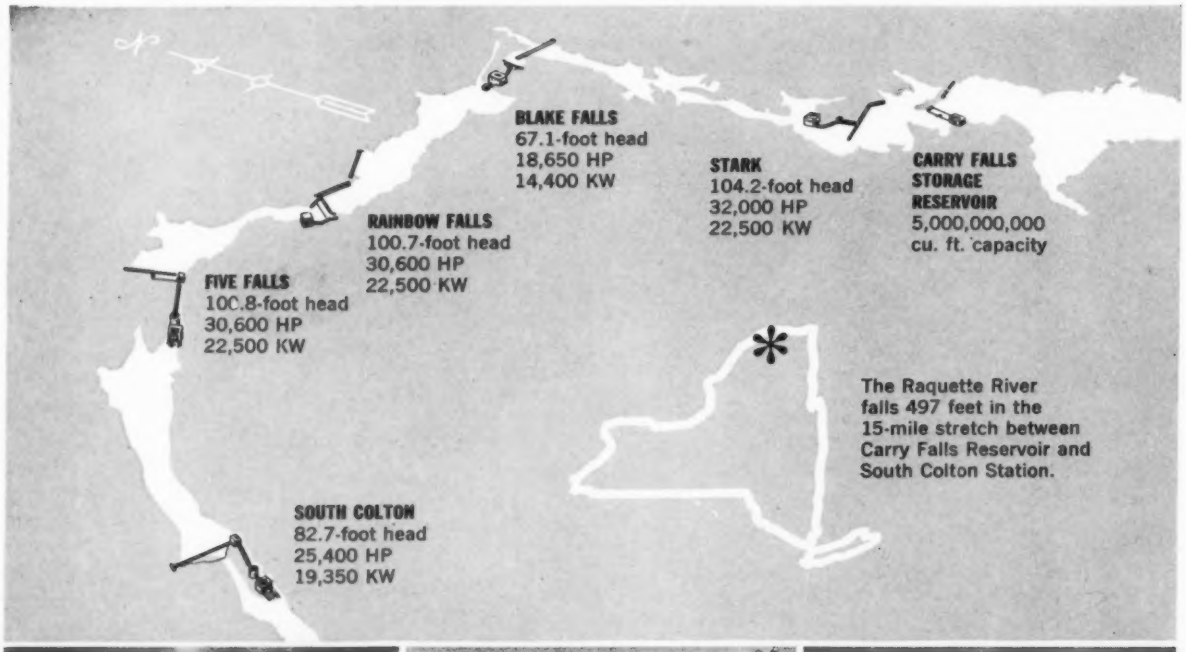
## AB KARLSTADS MEKANISKA WERKSTAD

**KARLSTAD - SWEDEN**

Representatives in Canada: A. Johnson & Co. (Canada) Ltd., 607 Shell Tower Building, Montreal 2

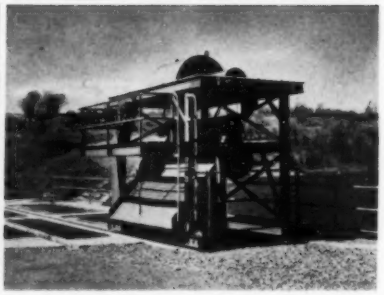
**For Harrsele Power Plant in Sweden, KMW have on order three Francis turbines, each developing 88,000 H.P. at 173 feet net head and 125 r.p.m. The first unit was put into operation in September, 1957.**

The picture shows one of the runners in our workshops. It is of welded construction according to our patented method.



South Colton powerhouse is typical of all 5 unattended stations. Supervisory control of automatic operation will be from Colton, 7 miles downstream.

Two SMS sliding gates with 50,000-lb. twin-drum cable hoists at Carry Falls Dam are designed for free discharge under a 58-foot head. This site can be converted to a hydro plant later if desired.



SMS self-dumping trash rakes operate directly on rack bars, ride down over obstructions and work them loose with a freedom of movement that assures fast, easy cleaning.

## 5 New Stations On Raquette River Equipped with SMS TURBINES AND ACCESSORIES

To further harness the Raquette River in northern New York, the Niagara Mohawk Power Corp. is now completing a series of five new power plants and a large storage reservoir. Each of these automatic, peak-load stations is equipped with an SMS-Francis turbine. SMS intake gates and twin-drum cable hoists, as well as trash rakes, are also used.

Working in close conjunction with Niagara Mohawk's engineers, SMS used two runner designs in the same basic wheel case for all five units. One runner design was used for the lower head turbines at South Colton and Blake, while another was used for the higher head turbines at Five Falls, Rainbow and Stark. This meant initial economy, and will provide operating and maintenance savings.

Each of the three lower stations uses self-dumping trash rakes at the turbine inlets. This design makes operation quicker and easier, cleans a greater area faster. For full information on these new trash rakes, or on other SMS accessories and hydraulic turbines, write S. Morgan Smith Co., York, Penna.

More Power To . . .

LIVE BETTER ELECTRICALLY

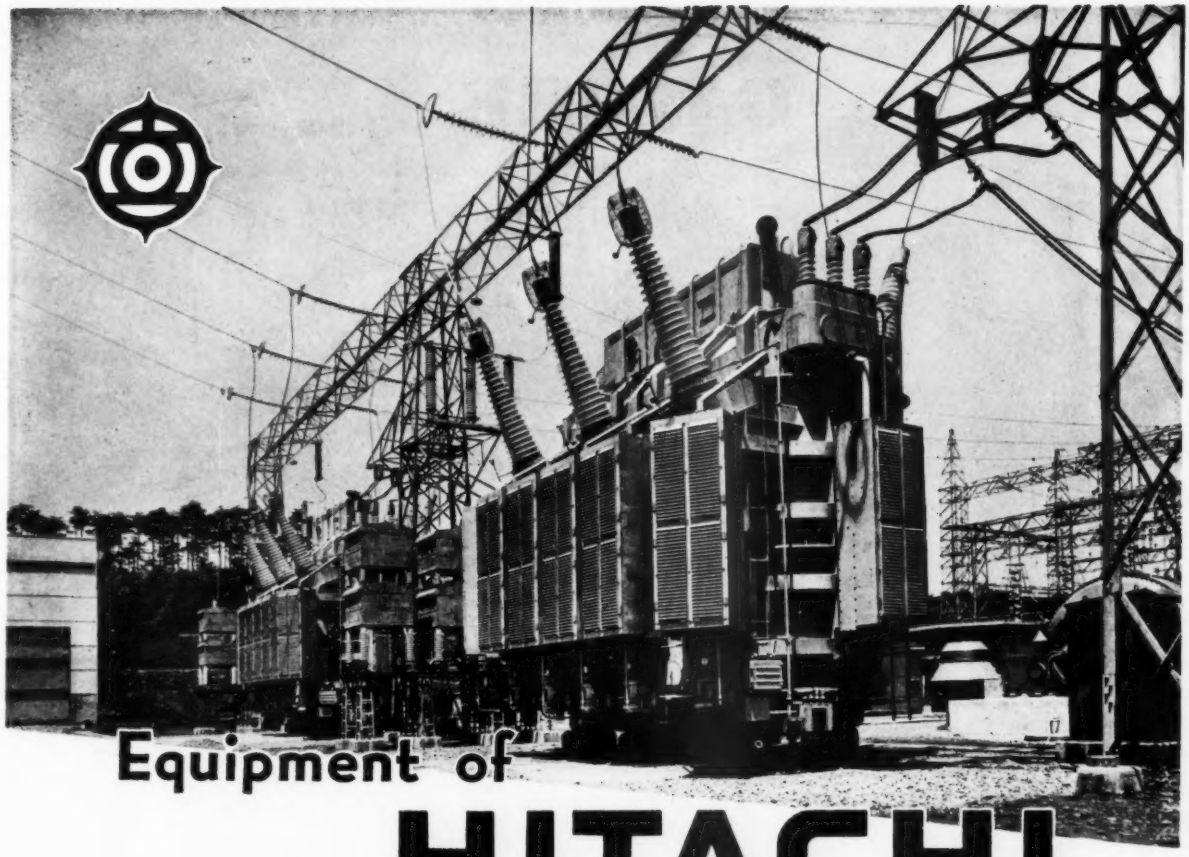
S. MORGAN SMITH

HYDRODYNAMICS

AFFILIATE: S. MORGAN SMITH, CANADA, LIMITED, TORONTO

Licensees: The Harland Engineering Company, Ltd., Alloa, Scotland • Tokyo Shibaura Electric Co. Ltd., Japan

Rotovalves • Ball Valves • R-S Butterfly Valves • Free-Discharge Valves • Liquid Heaters • Pumps • Hydraulic Turbines & Accessories



# Equipment of HITACHI

## for Substation Service

The photo shows Hitachi's 156,000 kVA super high-voltage transformers in service at the Nishi Tokyo Substation of the Electric Power Development Co. These outdoor type transformers are of 3-phase, 3-winding, core type, forced oil and air-cooled system. The high and medium voltage winding of these transformers is provided with a Hitachi patent centrosurge winding to increase their series electrostatic capacity and improve impulse voltage characteristics.

MAIN PRODUCTS

Generators, Turbines, Transformers and Other Equipment for Power Plants and Substations.
Locomotives and Other Rolling Stock.
Motors, Cranes, Pumps, Compressors, Refrigerators and Other Industrial Machinery. Printing Presses, Machine Tools.

Household Electric Appliances. Electron Microscopes and Other Precision Scientific Instruments.
Telephones and Switchboards. Electron Tubes, Fluorescent and Incandescent Lamps.
Electric Wires and Cables. Steel and Iron Products.

**Cable Address: " HITACHY " TOKYO**

Hitachi, Ltd.
Tokyo Japan

# POWER GALORE ....

THE unharnessed forces of Nature present at once a threat—and an opportunity! We are concerned only with the latter, for it is the safe control of electric power, at all stages, that enables full use to be made of this natural force.

In this connection, "safe control," is the function of "Ferguson Pailin" Switchgear; this is installed at strategic points in supply system which in so many parts of the World, rely on water power as a motive force.

For example, switch units similar to the type ROP32 oil circuit-breaker shown, designed for 22 kV or 33 kV service and with an A.S.T.A. certified breaking capacity of up to 500 MVA, are operating satisfactorily in many outdoor substations, sometimes under extreme climatic conditions.

Particular attention has been given in the design of our outdoor circuit-breakers to the provision of maximum protection of vital parts against humidity, heat or cold.

Especially would we draw attention to the adaptability of this Switchgear to particular system requirements—a feature which is a byword among those familiar with "Ferguson Pailin" products.

*Another popular type of outdoor switch unit is the TTPO24 oil circuit-breaker, a triple-tank, frame mounted unit, with an A.S.T.A. certified performance of 1500 MVA at 33kV*

*Type ROP32 Oil Circuit-breaker*

**Ferguson Pailin** LIMITED *for Switchgear*

An A.E.I. Company

*Head Office & Works:* **HR. OPENSHAW MANCHESTER 11,** *Telephone :* DROylsden 1301 (Pte.Branch Ex)

LONDON OFFICE : Bush House, Aldwych, W.C.2 BIRMINGHAM OFFICE : Windsor House, 656 Chester Road, Erdington, 23 GLASGOW OFFICE : Central Chambers, 109 Hope Street, C.2.

REPRESENTED IN PRINCIPAL OVERSEAS TERRITORIES

**Water Power Experts all over the World rely on Steel Castings and Forgings made by Bochumer Verein**

**We manufacture and supply**
**Steel Castings:** Plain carbon steel up to 400 tons;
13% Cr and other alloyed steel up to 120 tons cast weights.
**Steel Forgings:** Plain carbon and alloyed steel up to 150 tons ingot weight.

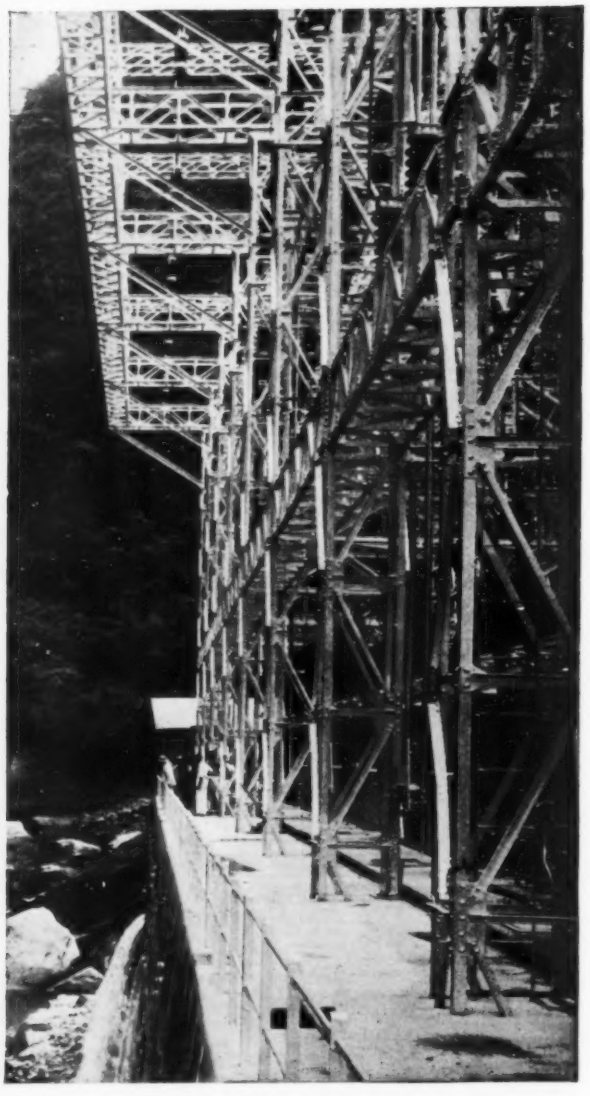
**BV-Vacuum Steel**
for complicated and highly stressed castings or those exposed to cavitation and for highly stressed forgings

Bochumer Verein
für Gusstahlfabrikation AG. BOCHUM

*Postbox 325, Bochum (Germany) · Telegrams: Gusstahl · Teleprinter: Gusstahl 0825831*

# S.P.P. Post Insulators were used on all the 110kv outdoor switchgear on the Jog Falls Hydro-electric Scheme

The outdoor switchgear at Jog Falls Power Station, in Mysore State, India, equipped with S.P.P. Cylindrical Post Insulators type P.701.



**STEATITE & PORCELAIN PRODUCTS LTD.**

Stourport-on-Severn, Worcestershire Telephone: Stourport 2271 Telegrams: Steatain, Stourport

3.77

# POWER TRANSFORMERS

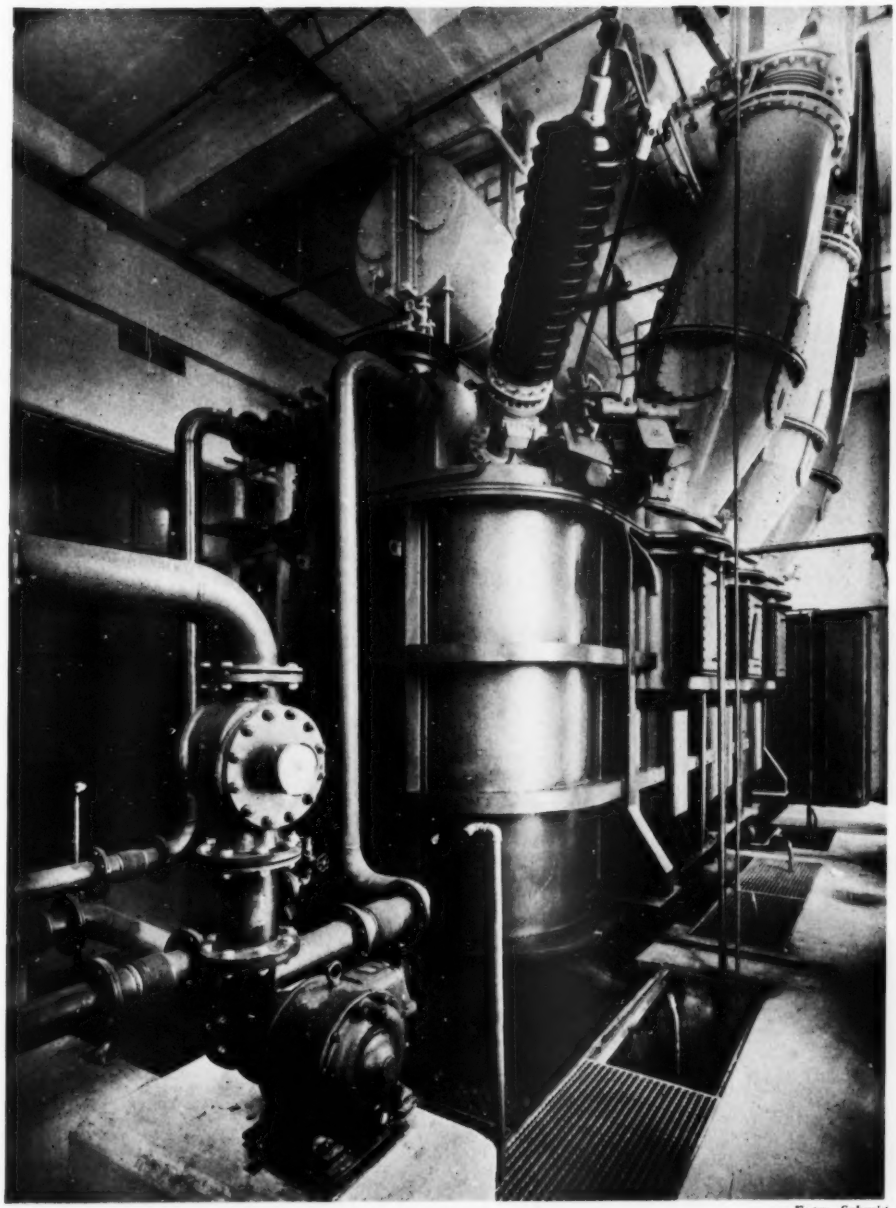


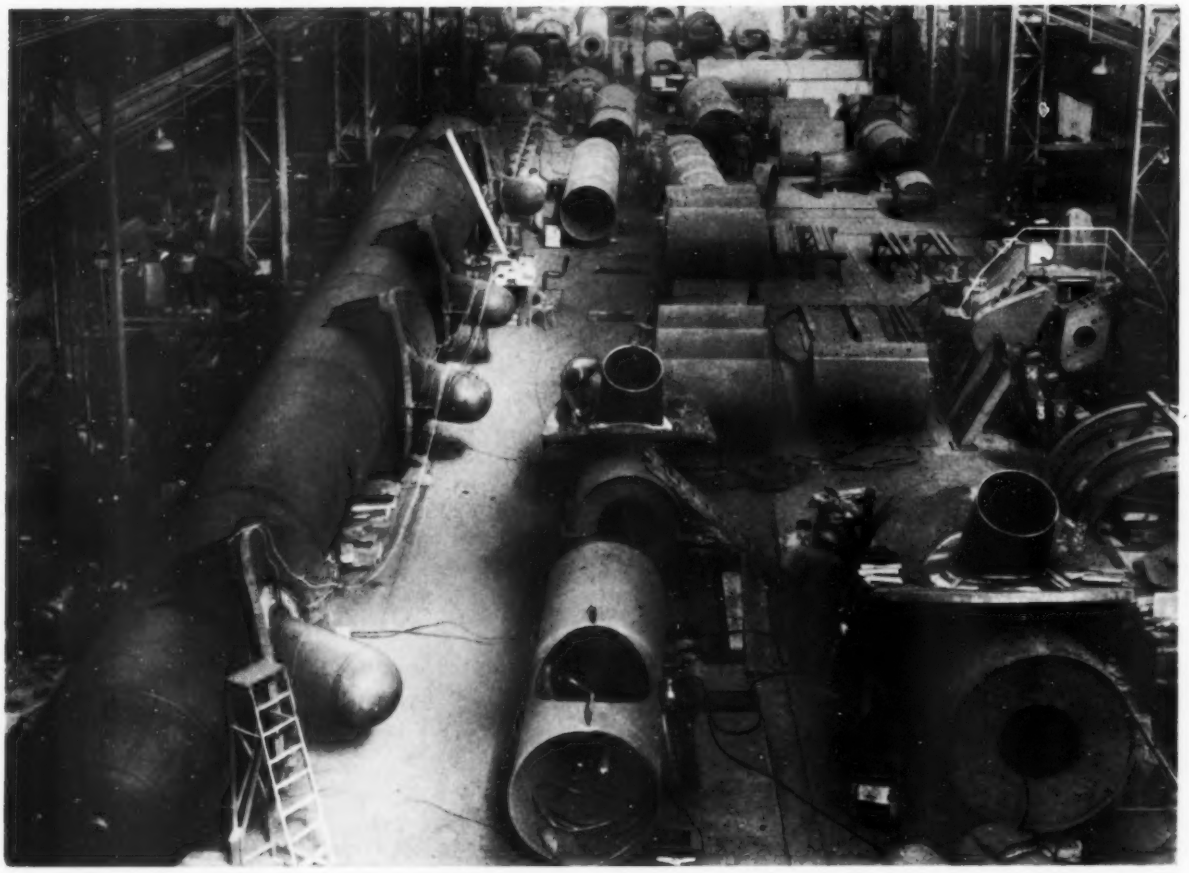
Foto: Schmid

One of the six ELIN regulating "power transformers" for the Austrian Danube Power Station Ybbs-Persenbeug, 45 MVA each, 225 kV ± 11% / 10.3 kV, with three directly mounted 220 kV cable end boxes pointing upward, HV neutral brought out; by means of a compressed-air operated disconnecting switch directly mounted on the relative bushing, this neutral can be solidly earthed. The transformer is designed for OFW cooling and is equipped with heat exchangers for heating purposes.

**"ELIN"**

AKTIENGESELLSCHAFT FÜR
ELEKTRISCHE INDUSTRIE
**VIENNA - AUSTRIA**

**Penstocks, pressure shafts linings,**
**Substation steel structures**
**Gantry and overhead travelling cranes**
**Pylons, water gates**



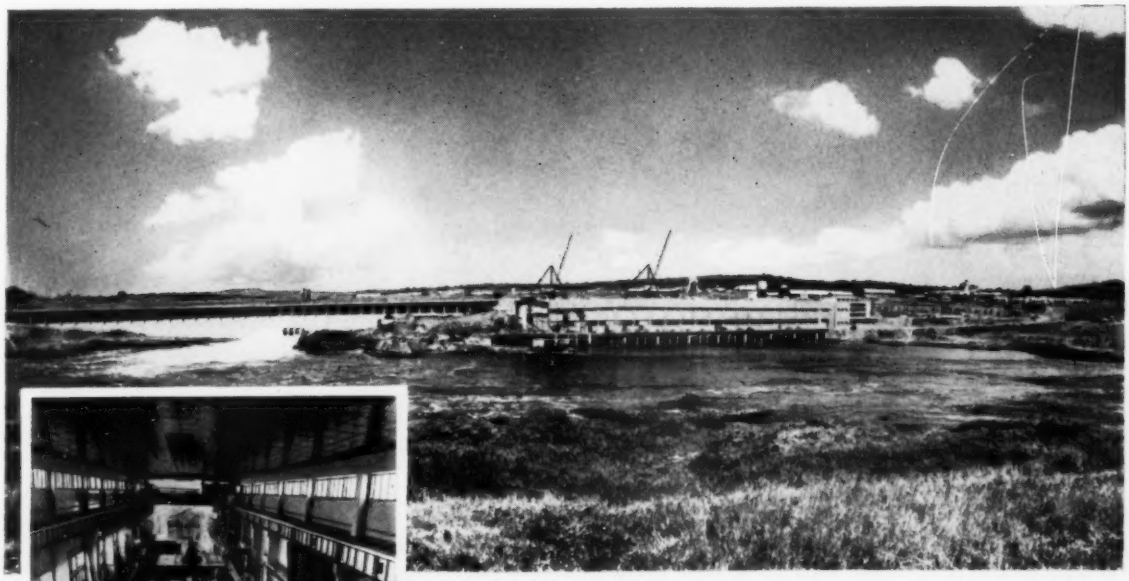
Downstream portion of the Grande Dixence Fionnay Power Station distribution pipe during tensometric shop tests. Max. wall thickness 52 mm., service pressure 96 at., test pressure 121 at.

# GIOVANOLA **Monthey - Switzerland**

HYDRO-ELECTRIC EQUIPMENT

# Power for Uganda by

The development of electric power for the Protectorate of Uganda ranks among many notable British achievements in which BTH has played a part. Bordering on Lake Victoria and divided by the Nile, Uganda covers an area of almost 94,000 sq. miles and has a population of over 4 millions. Here, as in countries throughout the world, BTH equipment is helping to produce power for greater prosperity, by harnessing natural resources of energy.



*The first three BTH alternators in service.*

The great hydro-electric project at Owen Falls includes eight BTH 16,700-kVA, 11,000-V vertical shaft alternators driven by Boving Kaplan turbines. BTH are also supplying electronic-amplidyne voltage regulators, control gear and ancillary equipment, 11-kV switchgear, and 20,000-kVA 33/132-kV transformers.

## BRITISH THOMSON-HOUSTON

THE BRITISH THOMSON-HOUSTON COMPANY LIMITED · RUGBY · ENGLAND

*Member of the AEI group of companies*

A4940

# From a scribble on a memo pad...

The merest outline is sufficient when you call in Crompton Parkinson Ltd. The engineers of their Contract Department are used to taking over a job when it is still just an idea—whether for the electrification of a small factory, a large town, or a whole countryside. From your outline they will prepare alternative schemes and estimates. When you have made your choice, they will carry the approved scheme through to completion. Crompton Parkinson have had nearly eighty years of experience in the design, manufacture and installation of electrical equipment of all kinds.

## ...complete electrification by

## Crompton Parkinson
LIMITED

ELECTRICAL EQUIPMENT

*MAKERS OF ELECTRIC MOTORS OF ALL KINDS · ALTERNATORS · GENERATORS · SWITCHGEAR · TRANSFORMERS · CABLES INSTRUMENTS · LAMPS · LIGHTING EQUIPMENT · BATTERIES · TRACTION EQUIPMENT · CEILING FANS · STUD WELDING EQUIPMENT.*

Crompton Parkinson Ltd., has branches and agencies in all parts of the world. If you cannot readily make contact, please write direct to us at Crompton House, Aldwych, London, W.C.2, England. Overseas Telegrams: Crompark London.

# HYDRAULIC STEEL CONSTRUCTION

## and PIPELINES for WATER POWER PLANTS

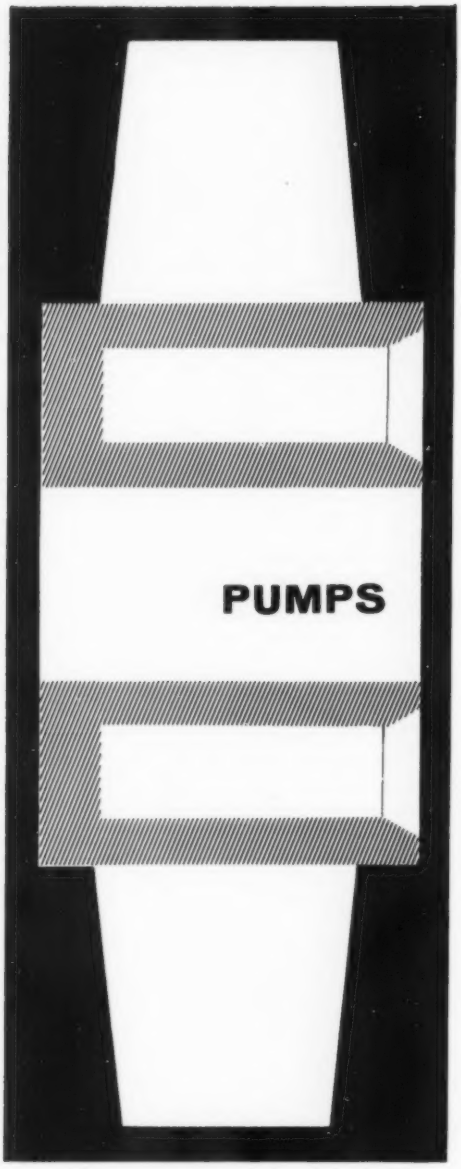
Completed erection at site of the high-pressure pipes for the tunnel lining to be supplied for the 'Schwarzach' Power Station.

# WAAGNER-BIRÓ

AKTIENGESELLSCHAFT

**WIEN** **GRAZ**

Head Office... WIEN V., MARGARETHENSTRASSE 70

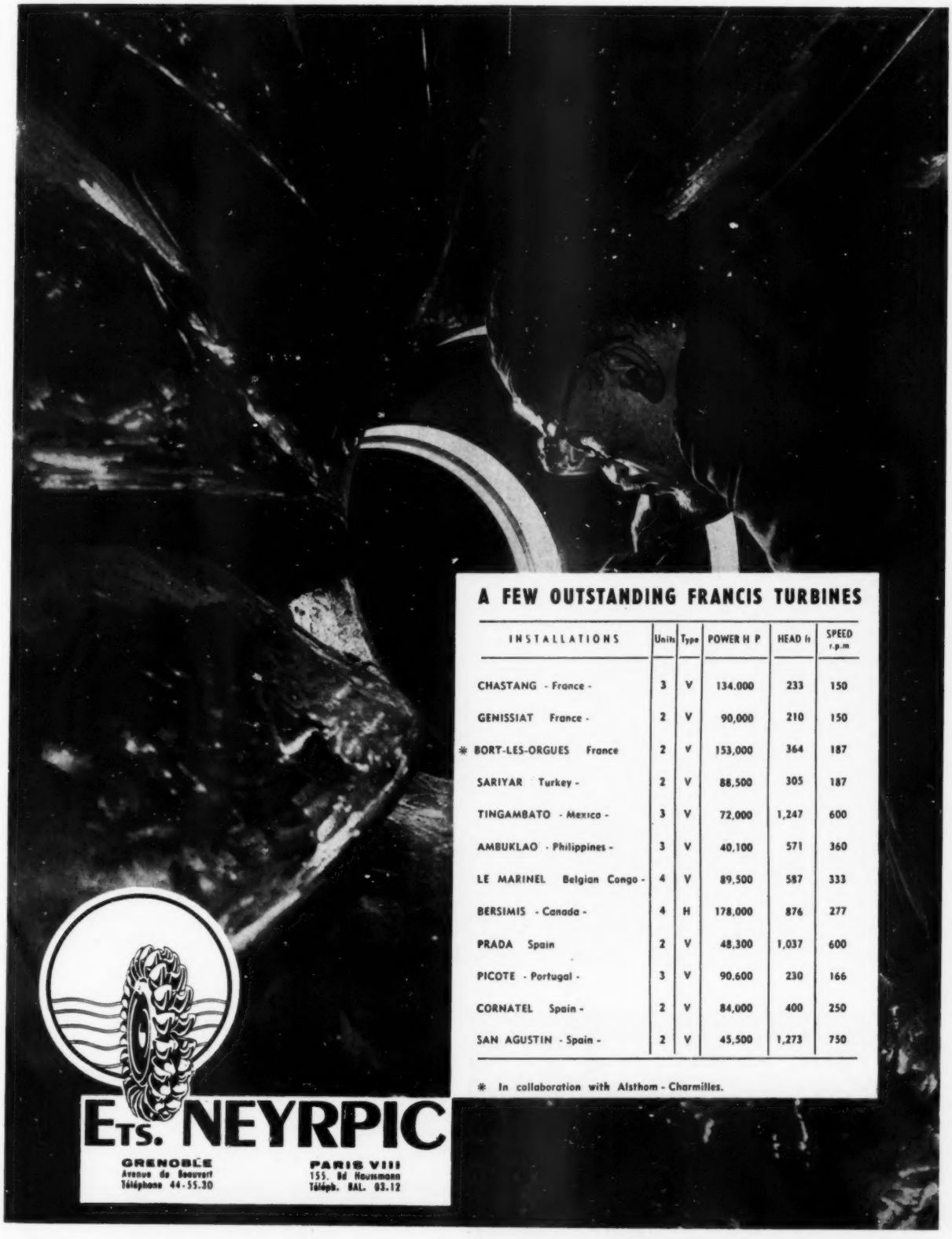



FOR PUMPING PLANTS
AND IRRIGATION
FOR AQUEDUCTS
FOR CIVIL - AGRICULTURAL
AND INDUSTRIAL USES

ELECTROMECHANICAL
INDUSTRIES

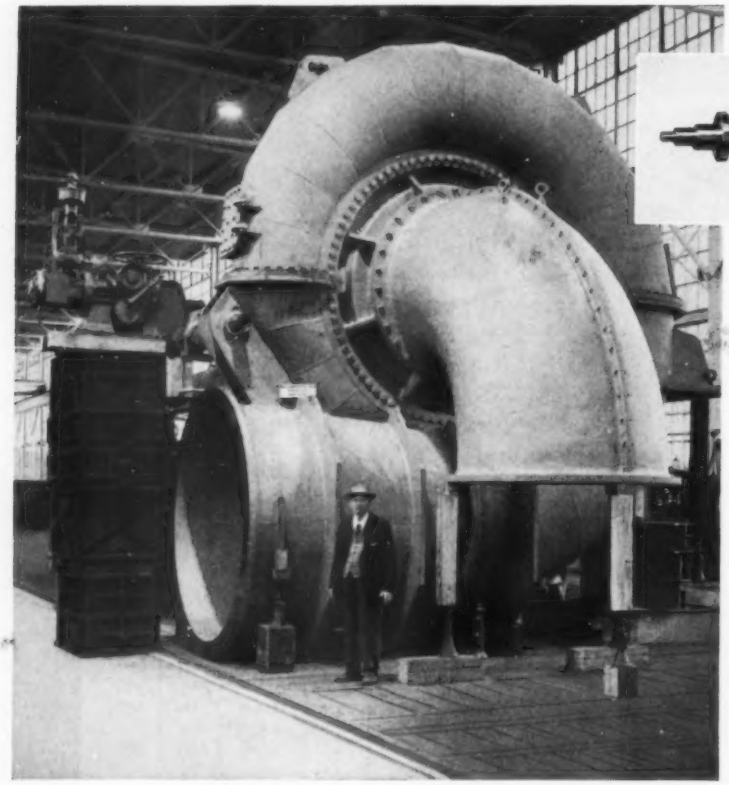
ARZIGNANO
Italy

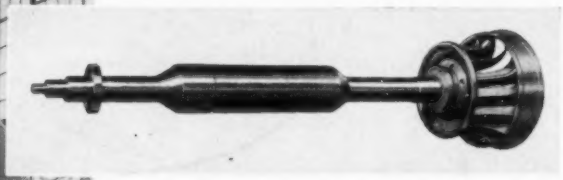
# PELLIZZARI


A FEW OUTSTANDING FRANCIS TURBINES
INSTALLATIONS | Units | Type | POWER H P | HEAD ft | SPEED r.p.m
CHASTANG - France - | 3 | V | 134.000 | 233 | 150
GENISSIAT France - | 2 | V | 90,000 | 210 | 150
* BORT-LES-ORGUES France | 2 | V | 153,000 | 364 | 187
SARIYAR Turkey - | 2 | V | 88,500 | 305 | 187
TINGAMBATO - Mexico - | 3 | V | 72,000 | 1,247 | 600
AMBUKLAO - Philippines - | 3 | V | 40,100 | 571 | 360
LE MARINEL Belgian Congo - | 4 | V | 89,500 | 587 | 333
BERSIMIS - Canada - | 4 | H | 178,000 | 876 | 277
PRADA Spain | 2 | V | 48,300 | 1,037 | 600
PICOTE - Portugal - | 3 | V | 90,600 | 230 | 166
CORNATEL Spain - | 2 | V | 84,000 | 400 | 250
SAN AGUSTIN - Spain - | 2 | V | 45,500 | 1,273 | 750
* In collaboration with Alsthom - Charmilles.
ETS. NEYRPIC
GRENOBLE
Avenue de Beauvert
Téléphone 44-55.30
PARIS VIII
155, Bd Haussmann
Téléph. BAL. 03.12

# LEFFEL BUILDS GIANT HORIZONTAL TURBINE FOR PLEASANT VALLEY

The low net head of 68 ft. at the Pleasant Valley Power Plant near Los Angeles required the design and construction by Leffel of a giant, horizontal spiral case turbine unit. This turbine, rated to develop 3,520 H.P. under the net head of 68 ft. at a speed of 257 R.P.M., drives a horizontal generator. A common shaft carries both the generator rotor and the stainless steel runner. A synchronous by-pass valve allows adjustment of flow for both turbine and by-pass discharge to meet water passage requirements. Photographs here show this giant turbine in various stages of production at the modern Leffel plant.





Leffel has the technical know-how and modern plant facilities to design and construct efficient, economical, rugged turbines of most types and capacities. And Leffel provides fast, complete service. Field engineers are available to assist you in the original planning of your project, and to help you with the actual installation of your turbine.

If you're planning a new project, or the rehabilitation or expansion of old facilities, and you want fast, complete service, contact Leffel, producers of top performing turbines. Mail the coupon below, today, for complete information.

**LEFFEL HELPS YOU PRODUCE MORE POWER FOR PROGRESS**

1102-E

**THE JAMES LEFFEL & CO.**

FOUNDED IN 1862

MORE EFFICIENT HYDRAULIC POWER FOR 96 YEARS

**FREE LITERATURE**

**THE JAMES LEFFEL & COMPANY**
**Dept. W, SPRINGFIELD, OHIO, U.S.A.**

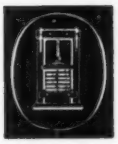
☐ Please send me more information on Leffel hydraulic turbines.

☐ Please have your representative call.

Name_____ Title_____

Company_____

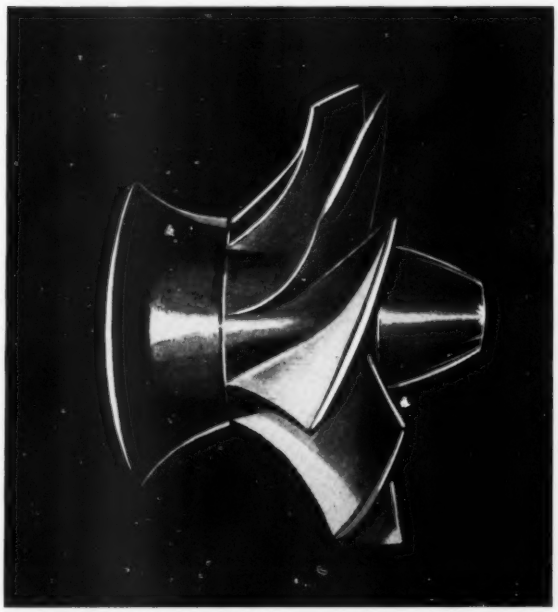
Address_____



AN AUTHORITATIVE AND IMPORTANT
BRITISH STANDARD PRACTICAL WORK

**CONTRIBUTORS**

A. C. R. ALBERY, M.C., B.A., A.M.I.C.E.
JACK ALLEN, D.Sc., F.R.S.E., M.I.C.E.
A. W. BISHOP, M.A., Ph.D., A.M.I.C.E.
P. L. BLACKSTONE, T.D., M.A., M.I.E.E.
G. A. BONNYMAN, M.I.C.E., A.M.I.Mech.E., D.I.C., A.C.G.I.
T. M. CHARLTON, M.A., B.Sc.(Eng.), A.M.I.Mech.E.
C. H. DAVIDSON, A.C.G.I., A.M.I.E.E.
P. E. DÉRIAZ, Dipl.Mech.Eng., Zurich
OSCAR ELSDEN, M.Sc., M.I.C.E.
H. L. FORD, A.R.I.B.A., A.M.T.P.I.
A. C. H. FROST, B.Sc.(Eng.), M.I.E.E., M.I.E.Aust.
J. M. GRAY
J. K. HUNTER, B.Sc., M.I.C.E., M.I.Mech.E., M.I.E.E.
CHARLES JAEGER, Docteur ès Sciences Techniques, Zurich.
H. G. KEEFE, M.I.C.E., M.I.Struct.E., M.Soc.C.E. (France)
J. H. LANDER, O.B.E., M.A., M.I.C.E.
G. H. LUNDGREN
C. H. MORTON, B.Sc., A.M.I.E.E.
S. NEVILLE, B.Sc.(Eng.), M.I.E.E., A.I.E.E.
P. L. OLSEN, B.Sc., A.M.I.E.E.
P. J. RYLE, B.Sc.(Eng.), M.I.E.E.
C. E. STILLE, A.C.G.I., B.Sc.(Eng.), D.I.C., A.M.I.Mech.E., A.M.I.E.E.
J. WARNOCK, M.C., M.I.C.E., M.I.Struct.E.
F. A. WEEMYS
F. H. WILLIAMS, B.Sc., M.I.C.E., M.I.E.E.



A Treatise in three volumes
by a team of the most prominent practising engineers
edited by **J. Guthrie Brown.**

The volumes are for the practising engineer
and the advanced student, and give
the latest methods adopted in this country
and on the Continent.

# HYDRO·ELECTRIC ENGINEERING PRACTICE

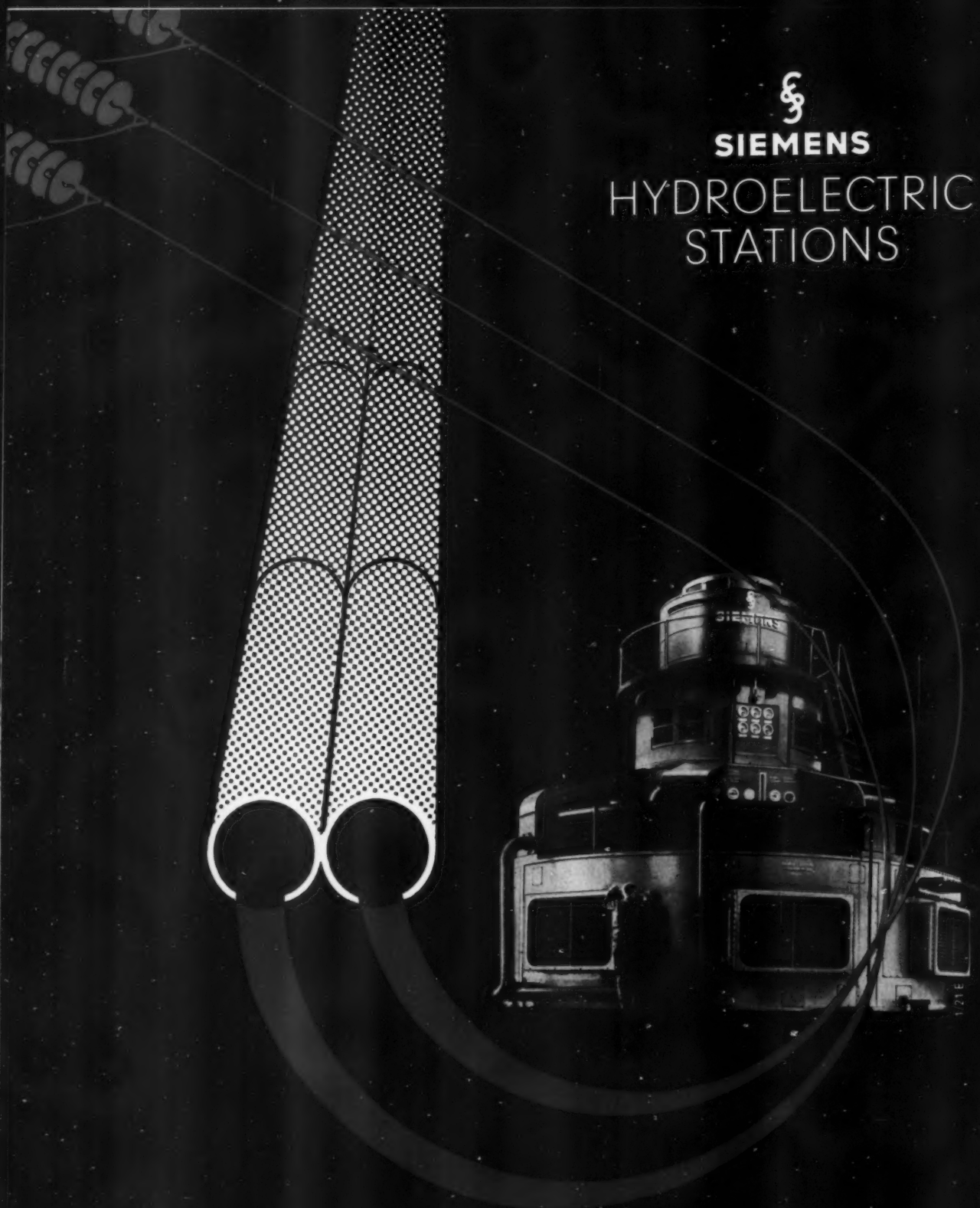
**Volume 1** · Nine Guineas
*CIVIL ENGINEERING*

**Volume 2** · Six Guineas
*MECHANICAL and ELECTRICAL ENGINEERING*

**Volume 3** · Four Guineas
*ECONOMICS, OPERATION and MAINTENANCE*

*Prospectus available on request to*

**BLACKIE & SON LTD.** 17, STANHOPE STREET, GLASGOW



SIEMENS

# HYDROELECTRIC STATIONS

SIEMENS-SCHUCKERTWERKE AKTIENGESELLSCHAFT
BERLIN · ERLANGEN

# WATER POWER

*A technical journal devoted to the study of all aspects of Hydro-electric developments*

Annually 40 shillings by post. Single Copies 2s. 6d.

Volume 10 Number 2

**CONTENTS FOR FEBRUARY, 1958**

Editorial: Electricity in Europe - - - - 41

Editorial Notes - - - - - - 42

The Kariba Hydro-Electric Scheme—II - - - 44
*By Sir Alexander Gibb and Partners*

Vibration Tests on Weirs and Bottom Gates—I - - 52
*By Dr. Ing. K. Petrikat*

The International Union of Geodesy and Geophysics—I 58

Cavitation in Turbomachines—II - - - 61
*By K. K. Shalnev*

Cumberland River Scheme - - - - 70
*By John Grindrod, B.A. (Com.)*

Book Reviews - - - - - - 75

Special-Duty Wagons for Kariba - - - - 77

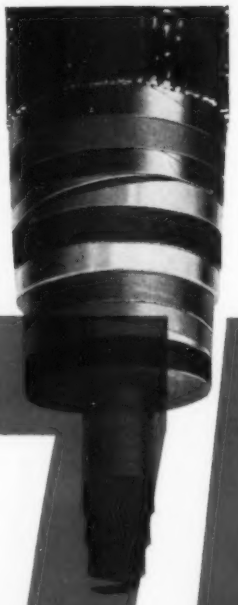
Abstracts from the World Technical Press - - 78

Editor: H. STOREY, M.C., B.Sc., M.I.M.E.

PUBLISHED BY TOTHILL PRESS LIMITED
33 Tothill Street, Westminster, London, S.W.1
Telegrams: Trazette, Parl. London. Telephone: Whitehall 9233 (20 lines)

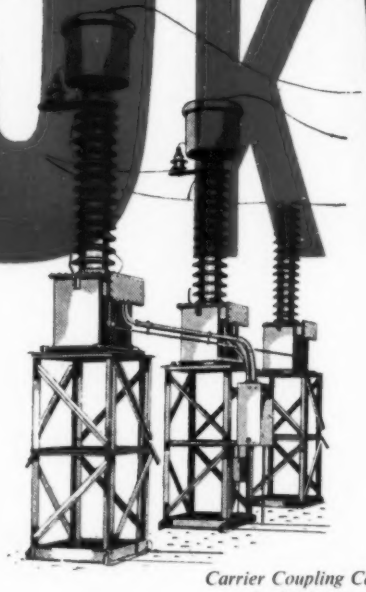
**MANCHESTER:** Century Insurance Building, St. Peter's Square. Telephone: Central 7667/8/9
**BIRMINGHAM:** 90 Hagley Road, Edgbaston. Telephone: Edgbaston 2466
**NEWCASTLE-ON-TYNE:** 21 Mosley Street. Telephone: 22239
**GLASGOW:** 139 Bothwell Street. Telephone: Central 4646
**LEEDS:** 70 Albion Street. Telephone: 27174
**BRISTOL:** 8 Upper Berkeley Place, Clifton. Telephone: Bristol 21930

275kV Oil-filled Cable



# 275kV transmission

275 kV Overhead Lines



Carrier Coupling Capacitors for 275kV System

## designed • manufactured • installed

## by the BICC Group

BRITISH INSULATED CALLENDER'S CABLES LIMITED • 21 BLOOMSBURY STREET, LONDON, W.C.1

WATER POWER

*A technical journal devoted to the study of all aspects of Hydro-Electric Development*

# Electricity in Europe

THE Organisation for European Economic Co-operation (O.E.E.C.) has issued two publications recently dealing with several aspects of electric power supplies in Europe. The first of these* gives the findings of a mission, organised by the European Productivity Agency of the O.E.E.C., consisting of six experts from the United States and 20 from the member European countries. This mission made a six-weeks tour of power stations in Great Britain and the Continent with the object of assessing the progress made in hydro and thermal-power production and the interconnection of networks, visiting in all eleven European countries and inspecting 53 power stations, distributing centres and research centres.

The members found many interesting developments in hydro technique and in particular were impressed by the full use which is being made of sites at which large dams can be erected. Unfortunately these sites are becoming increasingly rare in Europe as apart from the difficulty of finding satisfactory topographical and geological conditions, the density of population, and the necessity to feed it, prohibits the flooding of substantial tracts of agricultural land by storage reservoirs. For these reasons it is concluded that the big seasonal high-head reservoirs in the Alpine region should be planned as far as possible with a view to maximum use in a thoroughly integrated network system covering as much of western Europe as possible. The part played by reservoir stations, it is pointed out, varies greatly from one country to another; where there is a predominance of thermal power, hydro stations with small or seasonal storage capacity can be very conveniently used for peaking purposes—much more conveniently, in fact, than in countries that are mainly dependent on hydro power. These differences would, however, be evened out to a large extent if networks were more extensively connected on an international basis. It is therefore recommended that the optimum ratio between available reservoir capacity and the total installed capacity should be worked out for a fully interconnected network. For this purpose it would be necessary to know how many hours each reservoir power station could work at full capacity, the volume of the reservoir and the volume of the natural flow into the reservoir between, say, October 1 to March 31. It is considered that a survey of this kind would enable each country to base its development programmes on the amount of national and international demand.

Without such an international interconnection seasonal storage reservoirs could be used in two ways; they could be exploited until empty at the end of winter—so ensuring maximum production—or they could be carefully husbanded until the beginning of the high-water period. The first method involves the risk of power cuts should the weather conditions delay the high-water period, while the second is scarcely likely to be profitable. With the possibility of international exchanges on a wide basis, however, it should be possible to husband reservoir water before the critical winter period and so avoid any risk of spring losses. In this connection, a statistical survey of each reservoir, based on long-term meteorological forecasts, has already enabled certain countries to specify the optimum rate at which it should be emptied. Curiously enough, the mission makes no general statement on pumped-storage schemes, but does give every emphasis to the need for planning long-term developments on an international basis so that thermal and hydro sources of power can be combined to secure optimum overall economy.

The second report issued by the O.E.E.C. is entitled "Survey of Electric Power Equipment" and is obtainable from the same address. It gives the findings of a survey by the Electricity Committee and is divided into two parts, the first dealing with plant development and the second with heavy equipment for power stations. The aim of this survey was to obtain similar information to that published by the

* "Production, Transmission and Distribution of Electricity in Europe." Published by The European Productivity Agency of the Organisation for European Economic Co-operation, 2 Rue André-Pascal, Paris XVI°.

"Electric Power Survey" issued by the Edison Electric Institute of the United States. This shows the changes which occur in electrical equipment and its technical characteristics and is thus invaluable in indicating trends. The O.E.E.C. report covers the period 1953–1960 and includes such information as the size of the generating units installed, or on order, both hydro and thermal, and transmission lines and their developments. In the hydro field 2,465 MW of capacity were installed in 1956, slightly more than in preceding years, viz., 2,319 MW in 1953, 2,431 MW in 1954 and 1,959 MW in 1955. Estimates for the coming years indicate that these levels will be more than maintained:—2,785 MW for 1958, 2,822 MW for 1959 and 2,659 MW for 1960. There appears to be a decided trend towards larger units as the years go on. In 1953, for instance, 1,055 large units (over 40 MW) were installed against 179 small ones (below 10 MW); whereas in 1956 the large units had increased to 1,960 and the small ones sunk to 74. Very few units below 10 MW, it is stated, are now being planned and these smaller sets are ignored in the wealth of statistics given

## Symposium on the Observation of Structures

THE *Transactions* have now been published of this symposium which took place in Lisbon, 1955. Some 54 papers were presented on the observation of structures and an exhibition was held of the instruments used. There are two volumes containing, in all, some 1,500 pages. In the general report, of which there are English and French versions, the objectives to be secured by making observations on structures are discussed by Messrs. Manuel Rocha, Ferry Borges and Lagenha Serafim, who also proceed to analyse the methods and apparatus used to determine safety and stability. During the sessions such matters as displacement, opening of joints, cracks, rotations, strains, stresses, temperature and moisture effects were exhaustively discussed, the properties and characteristics of materials evaluated, and observations on actual structures interpreted. Reference is made to important structures built in various countries during the last ten years or so, and their behaviour both during and after construction analysed in detail. All the material in these two volumes has been presented by experts, and forms a bulk of data which is necessarily of great value to hydro-electric engineers. The price of the two volumes, which are obtainable from Laboratório Nacional de Engenharia Civil, Av. do Brasil, Lisbon, Portugal, is ten and a half dollars.

## Italian Water Power Development in 1956

THE Annual Report on Italian electric industry recently published by the A.N.I.D.E.L. (National Association of Electric Power Generating and Distributing Companies), illustrates the development of Italian electric plants at the end of 1956. According to this report, the total capacity (spare machinery excluded) was 12,157,686 kW, an increase of over one million kW or approximately 9·5%. Other plants with a total of 1½ million kW were under construction. As to the various sources of energy, the capacity of hydraulic plants was 10,678,000 kW, representing an annual increase of 8·8%, whereas that of thermo-electric plants was 2,399,500 kW—an increase of 11·6%; the capacity of geothermo-electric plants was 269,000 kW with no increase.

Over 40,590 million kWh were generated by Italian plants in 1956, of which over 31,300 million kWh were generated by hydro-electric plants, 7,495 million kWh by thermo-electric plants, and 1,779 million kWh by geothermo-electric plants.

The consumption of electric power in Italy in 1956 was 840 kWh per head of population, over 70% of the total output being produced in North Italy. Here the consumption rate was almost 1,300 kWh per head of population, a rate which is equal or nearly equal to those in the main European industrial areas.

Water storage capacity was 3·6 million cu. m., with an increase of 5% over 1955. The development of the 220 and 150 kW networks reached 24,500 km., with an increase of about 5%.

Among the main hydro-plants put into operation during the year we may mention the Cimego plant of the Società Idroeletterica Alto Chiese, already described in this journal; the S. Floriano plant of the Società Industriale Avisio, where two Pelton sets were installed and another set is envisaged, with a total capacity of 195,000 kW under a head of 545 m.; and the Premadio plant of the A.E.M., Milan (City Electric Supply Board, Milan), which comprises a large underground power station where two Pelton sets are installed, with a total capacity of 150,000 kW, and three other sets with a 230,000 kW capacity are envisaged, under a head of 708 m.

## Hydraulics Research

THE Quarterly Bulletin of the Mechanical Engineering Division, National Research Council of Canada, Ottawa, refers to model studies which have been made in connection with the St. Lawrence Seaway Project and two other hydro-electric power projects. In the St. Lawrence model, the objective is to ascertain the flow conditions and so assist the designing of the navigational facilities that are to be erected, and in working out a constructional programme for the various works, including, of course, the building of the power plants.

The other researches are concerned with the design of a spillway and apron for a power scheme in the Yukon and with a two-mile section of the St. Maurice river with the idea of dredging the river bed downstream of the power house to create a higher head.

It should be understood that much of the work is undertaken for Government Services and private industry and is not fully described in the Bulletin.

## Consulting Engineers' Centenary

A HUNDRED years ago Sir Charles Fox (1810–1874) left contracting work and began to practise as a consulting engineer in partnership with his eldest son, later Sir Donald Fox. In 1912 Sir Ralph Freeman first joined the firm which now functions under the title of Freeman Fox & Partners. In the century that has elapsed since they were established, the firm have been responsible for many notable engineering projects. Among their achievements the Sydney Harbour Bridge is especially noteworthy, while another distinctive work was the design of the Dome of Discovery

and other buildings for the South Bank Exhibition. They have also designed many power stations, including those at Castle Donnington and High Marnham, and at present they are retained as the chief consultants to the Ffestiniog pumped-storage scheme, in which Kennedy & Donkin are advising on mechanical and electrical matters and James Williamson & Partners on the civil-engineering problems involved.

## Hungary Builds Hydro-electric Power Stations in Kashmir

HUNGARIAN technicians are to carry out the modernisation and expansion of the Ganderbal and Mohara power stations in Kashmir. The power stations will each have two Francis turbines, each with a capacity of 4,750 kW, and the work is due to be completed by the end of 1959. Equipment for the power stations is being made at the Klement Gottwald Factory, the Ganz Wagon Works and the Electric Station Assembly Company, in Hungary.

## British Newfoundland Corporation Projects

THE extension during 1957 of the original engineering studies carried out by the British Newfoundland Corporation on the Hamilton River, Labrador, has disclosed that a development could be begun on a scale as low as 100 MW by temporarily diverting the Hamilton into the Valley River. This would increase flexibility and ease the task of building up sufficient demand for power to justify construction.

A power demand is foreshadowed by an investigation now being carried out by British Newfoundland Exploration Limited ("Brinex"), a subsidiary of British Newfoundland Corporation Limited, on a uranium prospect in Labrador 125 air miles north-east of Goose Bay. A mining operation of the order of 200 tons a day appears to be possible.

The intensive investigation of the power potential in the Bay d'Espoir region of Newfoundland proper was completed during the year, and the results of the survey will be available shortly. Preliminary indications are that some 350,000 h.p. at the site can be developed simply and economically in stages of 70,000 h.p. With the conclusion of this survey, British Newfoundland Corporation is in a position to quote a firm price for power to consumers and to start development as soon as justified.

## Hydro Power and Fish

A SUB-COMMITTEE of inquiry, appointed by the Secretary of State for Scotland to investigate the operation of fish passes and lifts, has absolved The North of Scotland Hydro-Electric Board from any appreciable interference with the fish life of Scottish rivers. The number of smolts injured by passing through power-station turbines is stated to be quite negligible. The inquiry conducted under the chairmanship of Professor Sir James Gray, Chair of Zoology, Cambridge University, deals with 16 dams built for hydro-electric purposes on seven Scottish rivers. The committee are of the opinion that there should be a limit to the expenditure and effort devoted to improving the passes for descending kelts because fish which have spawned once and return to the sea form only five per cent. of the run in later years. The number of kelts recorded in the fish pass at Pitlochry was surprisingly low and the committee consider that a check should be made on those passing over the dam during spill periods. Also, they recommend that consideration should be given to the possibility of studying the reactions of kelts to the flow conditions experienced at fish-pass entrances.

On the question of smolts, the committee say that on the limited evidence available, the number injured when passing through the turbines is probably negligible, but that this should be verified by experiments.

Special mention is made of Dunalastair on the River Tummel. In addition to the overfall type of pass, there is a small overfall sluice kept open for smolts. These works had been assumed to be satisfactory until detailed observations were taken in connection with an electric fish stopper. These showed that 25% of the smolts in the sample were pinned against the turbine-intake screens and killed. This intake is being entirely reconstructed by the Board. The committee consider that steps should be taken to prepare a programme of research designed to make good the gaps in present knowledge on smolt behaviour and that experiments should be designed to this end.

## Russo-Norwegian Pasvik River Scheme

FURTHER to the draft agreement, previously announced in this journal, between Norway and Russia for the joint development of the Pasvik River, which forms the frontier between the two countries, a final agreement has now been signed. The Russians plan to build three stations, one with a capacity of 45 MW and two of 17 MW. Norway intends to build a station at Skogfoss with a 65 MW capacity. The Soviet Union has indicated that it would like Norwegian contractors to build at least one of their stations, probably the largest.

## Power Expansion in British Columbia

EVIDENCE of British Columbia's continuing power expansion is contained in the 1958 budget figures announced recently by Mr. A. E. Grauer, President of B.C. Electric. The company forecasts a total expenditure of $98,600,000 to be devoted largely to the expansion of its electrical generation, transmission and distribution facilities. The biggest single item is the allocation of $30,800,000 for the company's second Bridge River development which is scheduled for completion in 1959. This project will have a total cost of over $60 million and the first of the four generating units is expected to be in service by May 1959.

Money for completion of the second submarine cable circuit to Vancouver Island is allowed for in an allotment of rather over $9 million for electrical generating stations, transmission lines, substations and distribution facilities for the Island.

---

## Mr. W. H. Parrack

We deeply regret to record the death on December 18, at the age of 67, of Mr. W. H. Parrack, a director of Tothill Press Limited, the company owning and publishing this journal, and Joint Managing Director of Odhams Press Limited, the parent company.

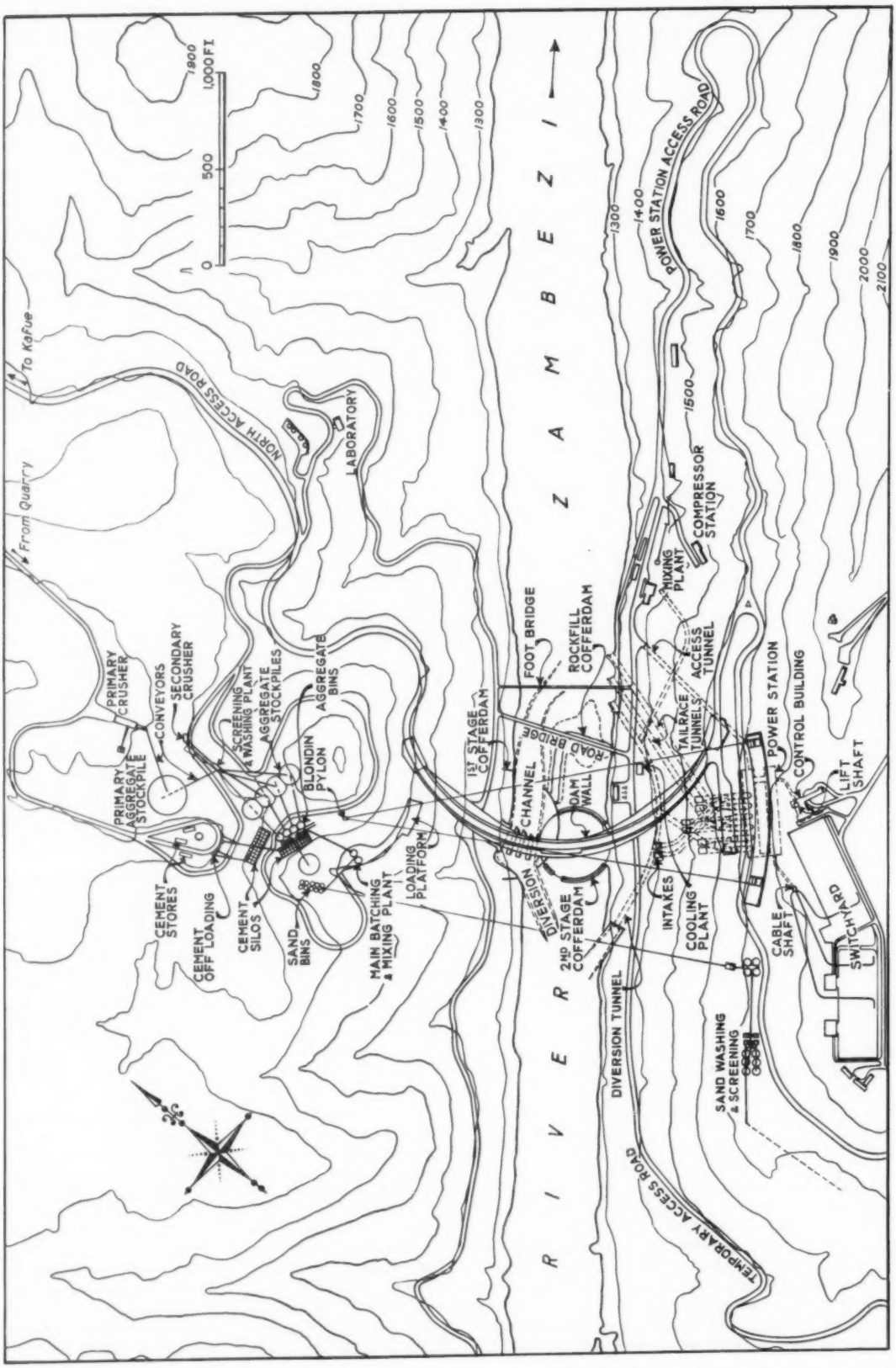



*Fig. 11. General plan of Kariba operations*

*Fig. 12. Night view of main dam works from south bank*

# The Kariba Hydro-Electric Scheme

By SIR ALEXANDER GIBB AND PARTNERS

PART TWO

THE special conditions which determined the scheme of operations were:

1. The large seasonal variations in the flow of the Zambezi which have been mentioned in the previous article;
2. The difficulty of diverting the river due to the confined nature of the site; and
3. The urgent need to produce some power at the earliest possible date to meet the requirements of the Federation's growing industries.

Diversion of the river during early stages of construction is being made by a 37 ft. diameter tunnel, 1,300 ft. long, in the right bank, and a channel leading through temporary openings in the dam on the left flank. The portion of the dam containing the temporary openings was constructed inside a thin circular arch concrete cofferdam; this cofferdam has been breached to enable the river to flow through the diversion channel. Between the channel and the right bank the river has been blocked by rock fill dumped from a temporary construction bridge. It was then possible to build, in still water, the main circular cofferdam enclosing the centre part of the dam foundations. Later, the diversion tunnel and temporary openings will be sealed and the upper parts of the dam will be constructed ahead of the rising water. This will enable impounding to start as soon as possible: also some of the machines can be put into commission during filling of the reservoir, though of course under a reduced head.

**The Construction Programme**

The construction programme described by reference to Figs. 1 and 2 (Part One) is influenced by the annual flood season which occurs between December and June each year.

1955-1956 Construction of diversion tunnel, channel and left bank cofferdam.

1956-1957 Excavation of foundations and concreting

*Fig. 13. Aerial view of dam site looking north, 22 November, 1957*

of lower levels of dam within left bank cofferdam.

1957 Construction and dewatering of main cofferdam.

1958 Excavation of foundation and concreting of lower levels of centre part of dam.
Sealing diversion tunnel and temporary openings.
Impounding begins.

1960 Dam completed.

The construction of the dam should be complete in August 1960, and given average rainfall the reservoir will be full by 1963, though floods or droughts could advance or retard this date by two years.

The first set should be generating under reduced head by January 1960, followed by the second set four months later, and the third by November 1960, most of the output at this stage going to the Copperbelt, which has first priority. The following year more water will be available, the next two sets will be in commission and supplies to Southern Rhodesia are scheduled to start. The sixth set was planned for commissioning by 1966 to meet the anticipated growth in demand, but it may be installed at an earlier date to make use of the surplus energy available at Kariba to effect savings in the operating costs at the existing coal fired stations.

The second stage—construction and equipment of the left-bank power station—will follow; the first stage, however, includes some preliminary work required to allow construction of the left bank intakes without dewatering the reservoir.

**Progress of the Work**

It was realised at the start that some time must be allowed for the preparation of contract documents and examination of tenders before the main civil engineering contract—which covers construction of the dam and right bank power station with its intake, tailrace and access tunnels—could be placed. Everything possible was done to expedite matters meanwhile. The joint civil consultants immediately established an office in Salisbury under the name of Gibb, Coyne, Sogei (Kariba) (Pvt) Ltd. and a number of preparatory works were put in hand to give the main civil contractor, when appointed, a flying start. These included:—

*Geology.* Detailed investigations confirmed the previous opinion that the site is favourable, the rock being metamorphic and mainly composed of sound biotite gneiss. A small trial tunnel was driven to investigate conditions in the underground power house.

*Communications.* An airstrip was constructed near the site and was operating busily by the summer of 1956, reducing the 244 miles journey by road, much of it rough, from Salisbury to about an hour by aeroplane. Construction of access roads was started, one 42 miles long linking Kariba with the Salisbury-Chirundu road at Makuti, another running northwards to connect with the Chirundu—Lusaka road, a length of 45 miles. A suspension footbridge and a road bridge were built across the river just below the dam site.

*Housing.* A quick start was made with accommodation for the temporary population of some 10,000 workers and staff and their families, European and African—a considerable town planning exercise in itself. Besides the two colonies of all-electric dwellings with purified water supply and water-borne sewerage, there will be a hotel, swimming pool, playing fields, meeting halls, schools, shops, hospital, post office and two banks—all ledged picturesquely on the hills that rise steeply from the river to a height of nearly 3,000 ft. above sea level. This necessary adjunct to construction has alone cost nearly £3½ million, Richard Costain (S.R.) Ltd. being the contractor. As concrete walls and asbestos or corrugated iron roofs are the cheapest form of construction here, even for buildings designated as temporary, there is a good chance that many of them will in fact find permanent use. By early 1957 accommodation for 6,000 persons (Europeans and Africans) was ready.

*The Diversion Works.* A preliminary contract for the execution of the diversion works was placed with

*Fig. 14. Downstream section of second-stage cofferdam*

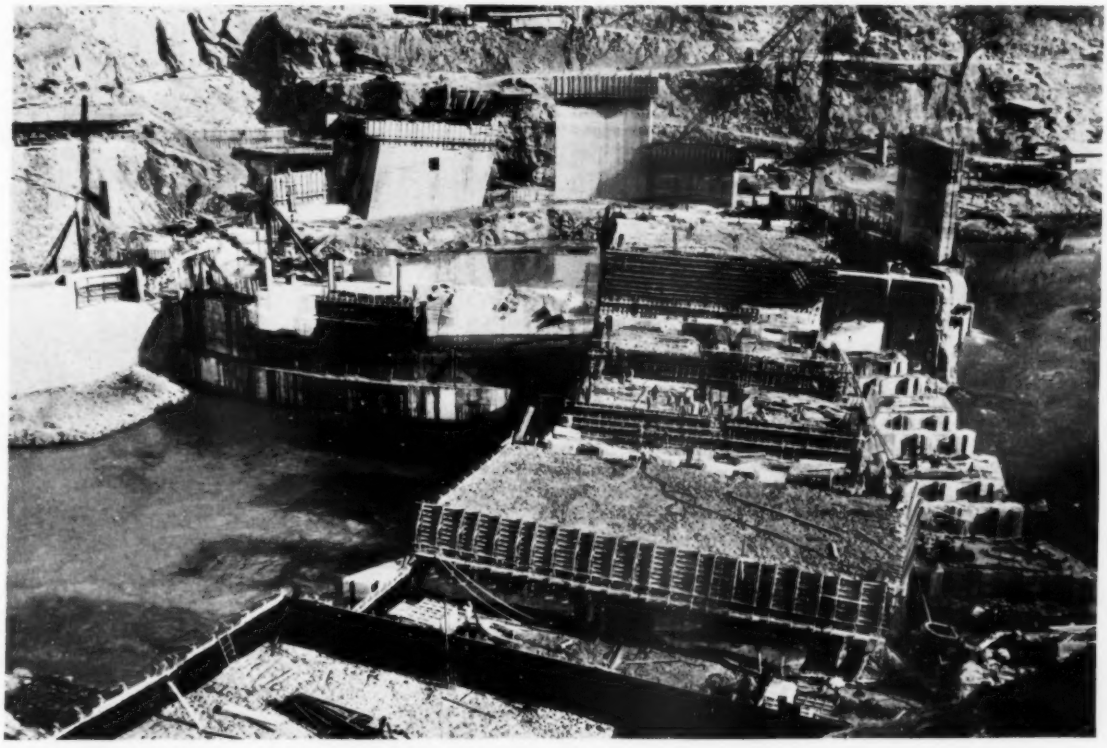


*Fig. 15. View of works looking south-east*

The Cementation Company Ltd. in June 1955. Excavation of the diversion tunnel portals and the construction of the tunnel 1,300 ft. long and 33 ft. by 40 ft. in section, was begun in September 1955. Initial work on the diversion channel involving 100,000 cu. yards of rock excavation, and the excavation for and start of construction of the left bank cofferdam, were carried out at the same time. The cofferdam is a substantial structure about 60 ft. maximum height and 900 ft. long measured at the crest, and contains some 12,000 cu. yards of concrete. It was essential to complete it before the December floods and it has to be borne in mind that the river can rise up to 70 ft. in a season.

After the start of the main civil engineering contract, the initial Cementation contract was brought to a close on August 31, 1956, and by this time the major part of these works had been completed, the tunnel and cofferdam being finally completed in November 1956.

**Main Civil Engineering Contract**

These preparatory efforts advanced the final completion date by at least twelve months. The main contract—believed to be one of the largest single civil engineering contracts ever placed—was awarded in July, 1956, to a group of four Italian firms operating as Impresit (Kariba) (Pvt) Ltd. and the advance guard of the contractor's staff soon began to arrive with their families by the 'plane-load and take up their quarters alongside the considerable numbers already installed in the growing Kariba townships. The latest population figures reported are 1,500 European and 8,500 African.

Actual work on the main contract has made a good start. Already the right bank is pitted with large caverns—the beginnings of excavation for the power house and its tunnels, described by a writer on the spot as "a warren as great as ever there was in the days of the rabbit." On November 6, 1956, Lord Malvern placed the first concrete in the main dam.

The main contractor suffered a set-back in March, 1957, when the highest flood experienced since recording was begun 51 years before inundated the left-bank cofferdam. Unusual as such an event might be, it was allowed for in the design of the works and the contractor had ample warning to enable him to remove most of his plant to safety, but a valuable six weeks was lost, leaving him hard pressed to keep to schedule. By the beginning of July 1957, construction of the dam within the left-bank cofferdam was sufficiently advanced to enable the latter to be breached and the river to be diverted through the temporary openings.

Meanwhile, dumping of the rock fill cofferdam proceeded steadily in preparation for a start last summer on construction of the second-stage cofferdam.

In the underground works excavation and concreting of the machine hall roof has been completed according to programme, and the bulk excavation downwards towards the turbine foundations is proceeding. Work on the intakes and shafts has started.

**Costs**

The panel of French experts, reporting in January,

*Fig. 16. Downstream end of machine hall from south wall side*

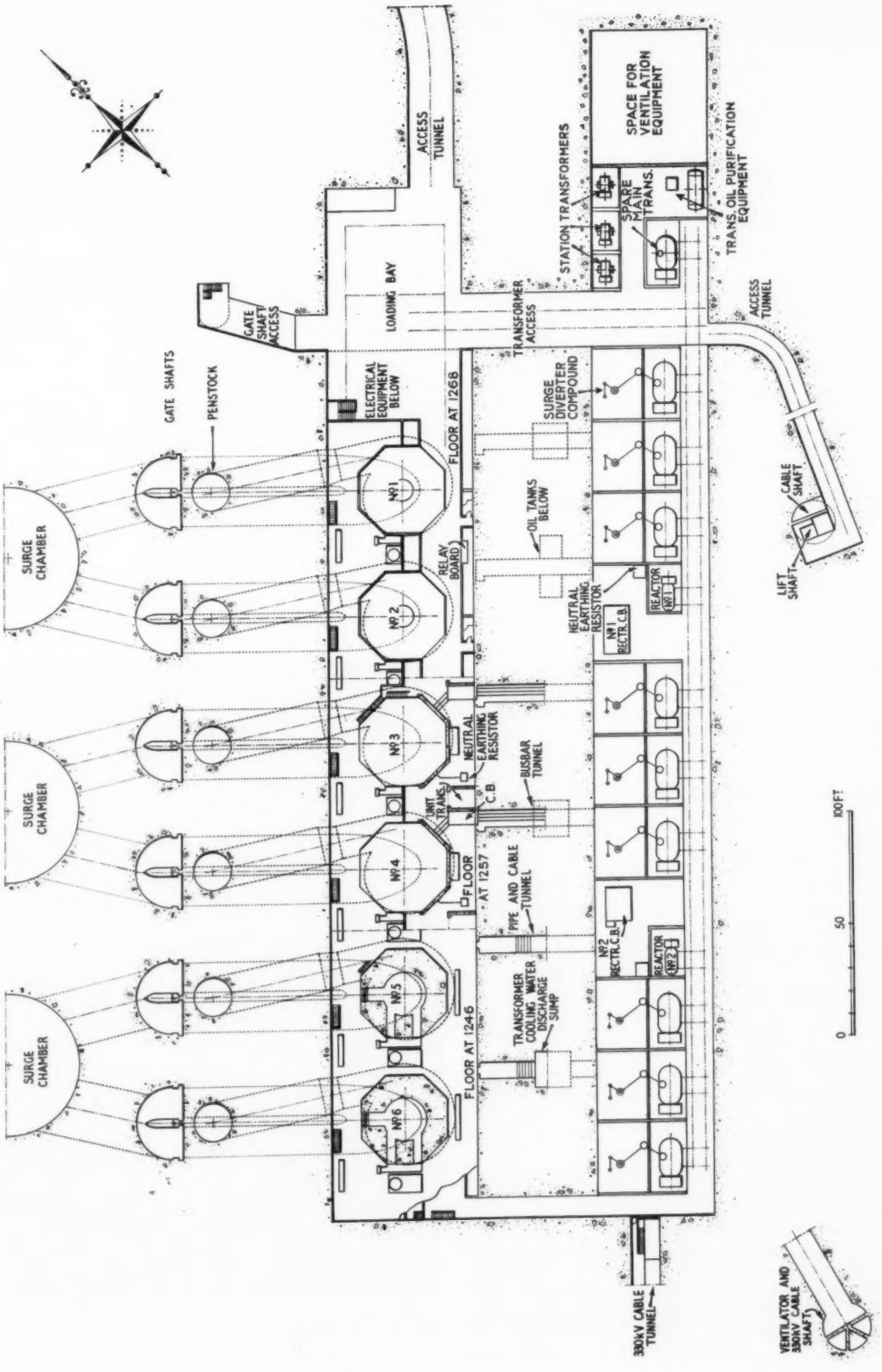



*Fig. 17. General plan of underground power house*

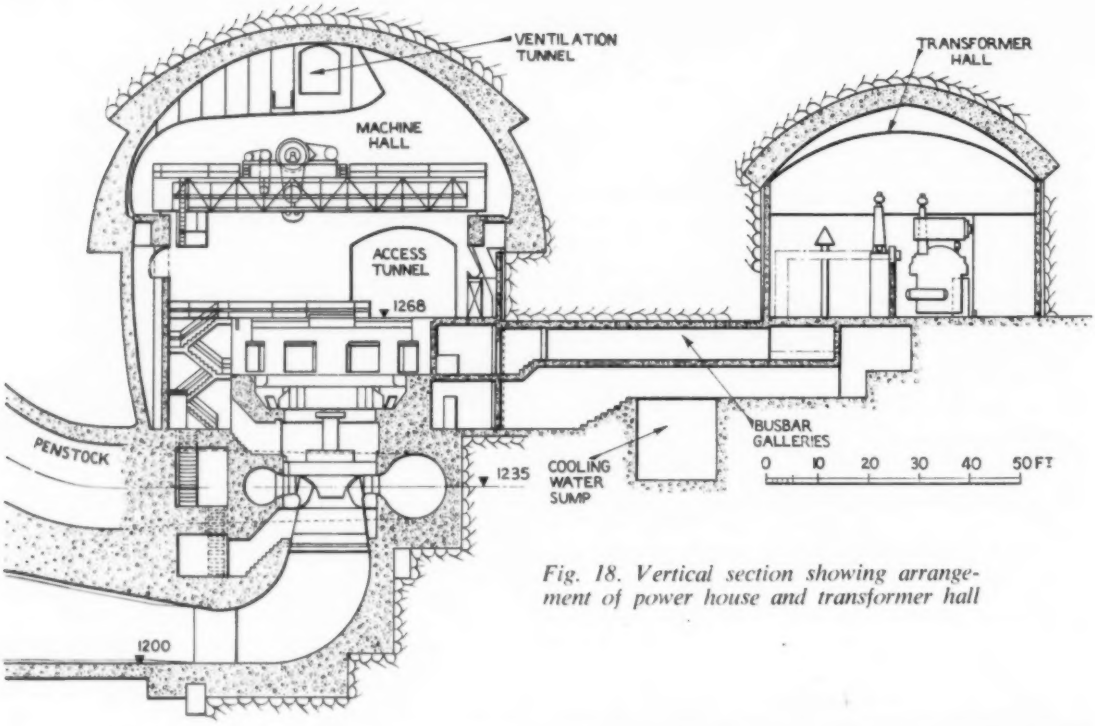



*Fig. 18. Vertical section showing arrangement of power house and transformer hall*

1955, gave it as their opinion that, in general, hydro-electric development could provide power for the Rhodesias at a cheaper rate than any expansion of existing thermal stations; and that Kariba in particular would constitute "a powerful provider of guaranteed energy at a price among the lowest in the world." The following provisional figures, published by the Chairman of the Federal Power Board, give support to that judgment, though it must be understood that they were based on estimates of construction, loan interest and other charges, and of demand, which are subject to revision.

The capital cost of construction was assessed (before receipt of tenders for the main contracts) at £79½ million for the first stage to produce 500 MW, and £113¼ million for the complete scheme. These figures include the cost of transmission and are equivalent to £159 per kW of installed capacity for the first stage, falling to £94 10s. on completion. If the cost of transmission is excluded, the figures are reduced to £113 and £63 per kW respectively, which compare with £120–£180 per kW for hydro-electric installations in Britain today. It should, however, be mentioned that the estimated load factor for the completed scheme at present is 78% and if this should be reduced by the installation of additional plant there will be a corresponding reduction in the capital cost per kW installed.

The overall cost per kW is higher than the corresponding figure for thermal stations but is offset by lower operating costs (a comparison which is largely influenced by the price of coal), a lower obsolescence factor, an insulation against inflation and—particularly applicable to stations used for peak load purposes—greater flexibility of output. Another factor

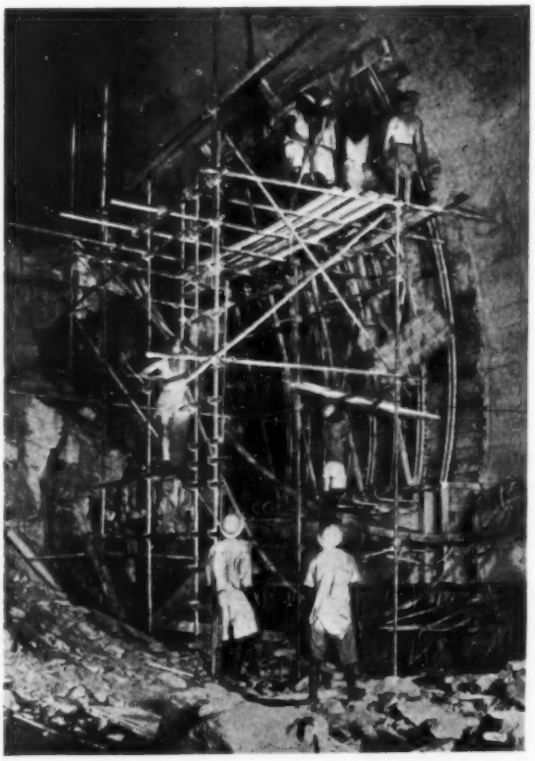


*Fig. 19. North wall of machine hall showing shuttering to second-stage vault concrete*

of special importance to the Federation is the relief of load on the railways represented by long hauls of coal.

The investment required for new thermal stations to meet the equivalent load was reckoned at £101 million—£12¼ million less than Kariba. On the other hand a comparative forecast of production costs over a period of about 10 years showed a balance of £44 million in favour of Kariba, making a net advantage of nearly £32 million: and from 1971 onwards the saving in annual costs should be nearly £10 million a year.

The cost per kWh of power delivered from Kariba at the busbars of the main receiving stations was estimated at 0·869d in 1961, 0·588d in 1962, followed by a steady fall to 0·283d in 1972. After 1981, when the burden of loan interest and redemption will have ceased, there should be a further reduction. The present average cost of production by the existing thermal stations at Salisbury, Bulawayo and Umniati is 0·8d.

As to price to consumers, little can be said at present. The Board will set its tariff as low as possible so as to ensure a high load factor and thereby to keep costs to a minimum. On the other hand it is bound by its agreement with the World Bank to set aside from revenue sufficient to meet half the cost of construction of the second stage. This, however, is an investment from current income which in its turn will produce fresh dividends.

**Benefits**

Kariba will represent an immense asset to the Federation, a relief to its hard-worked railways, and a lively stimulus to the growth of its industries. Industrial development, with the consequent rising of the standard of living of the African population, will be of the greatest economic benefit.

The dam will be one of the sights of Africa and, with its great lake, will constitute an attraction to tourists. The controlled tailwater might be used to irrigate large areas, and the surface of the lake could provide an economical means of transport. The development of commercial fishing is another possibility. These and other potential advantages are under examination by a recently appointed inter-Governmental Committee.

The following sentence provides a fitting conclusion to this brief account. It forms part of the Preface, signed by Lord Malvern, to a paper on the Kariba scheme prepared by the Federal authorities:—

> The Federal Government has given this Project a very high priority in its development planning for the next few years, and is convinced that it will be of enormous benefit not only to all sections of the population in the Federation of Rhodesia and Nyasaland but to all those nations of the free world who will benefit from the products which its power will help to produce.

Responsibility for construction and operation of the Kariba scheme, set up by the Federal Government, rests with the Federal Power Board. The civil engineering consultants appointed by the Board for the first stage of the Kariba project are Sir Alexander Gibb and Partners of London, Messrs. André Coyne and Jean Bellier of Paris, and the Société Générale d'Exploitations Industrielles of Paris, these three firms being amalgamated for the purpose of the Kariba project as Gibb, Coyne and Sogei (Kariba) (Private) Limited. The mechanical and electrical engineering consultants, similarly appointed, are Messrs. Merz and McLellan of London, Newcastle and Salisbury, Southern Rhodesia. Sir Alexander Gibbs and Partners (Africa), with Messrs. Jeffares and Green of Salisbury as co-consultants, are assisting with the road-works.

The Principal Contractors for the Scheme are as follows:

*Civil Engineering*

| | |
|---|---|
| Impresit Kariba (Pvt) Ltd. | Main cofferdam, dam, intakes and underground works, etc. |
| The Cementation Co. Ltd. | Left-bank cofferdam and diversion tunnel, and subcontractors to Impresit for sealing main cofferdam, grouting the dam and underground works. |
| Richard Costain (S.R.) Ltd. | Housing. |
| John Laing & Son (Rhodesia) | Access roads and railheads. |
| A. G. Burton Ltd. | Access road. |
| The Shell Co. of Rhodesia Ltd. | Petrol and oils. |
| Kariba Transport (Pvt) Ltd. | Transport. |
| Dorman Long (Africa) Ltd. | Bridges. |
| Etablissements Neyrpic | Intake and draft-tube gates, screens, and flood gates. |

*Mechanical and Electrical Plant*

| | |
|---|---|
| Boving & Co. Ltd. | Water turbines |
| Metropolitan Vickers Electrical Export Co. Ltd. | Generators. |
| Babcock & Wilcox Ltd. | Cranes. |
| English Electric Co. Ltd.<br>Ferranti Ltd. | Transformers. |
| British Thomson-Houston Co. Ltd.<br>Brown Boveri & Co. Ltd.<br>Metropolitan-Vickers Electrical Export Co. Ltd. | Switchgear. |
| British Insulated Callenders Cables Ltd. | 330 kV ancillary cables |
| Rhodesian Power Lines (Pvt) Ltd. | Transmission Lines. |

NOTE. The generator transformers attributed in Part I to Ferranti Limited are in fact being supplied by English Electric Co. Ltd. Ferranti Limited are supplying the 330 kV substation step-down transformers.

---

**Vickers Limited** announce the formation of a new subsidiary company—Vickers-Armstrongs (Tractors) Canada Limited—with a registered office in Montreal. The company have already opened a depot in Vancouver and a further one will be opened shortly in Toronto. The Vancouver depot will serve provinces west of Ontario. This means that Vickers Canadian tractor users can now be assured of quick "off-the-shelf" service at all times. The secretary of the company is Mr. J. M. Anderson.

# Vibration Tests on Weirs and Bottom Gates

By DR. ING. K. PETRIKAT, Chief Engineer and Head of the Hydraulic Laboratory, Maschinenfabrik, Augsburg-Nürnberg A.G. Gustaysburg Works

ECONOMICAL design of hydraulic structures presupposes accurate knowledge of the loadings which occur in practice and the resultant stressing of the structure. The loading caused by flowing water must be determined by tests, as the effect of the boundary layer introduces an excessive uncertainty factor into theoretical calculations. In the flume of 0·6 m. width shown in Fig. 1, the model is provided with numerous holes in the middle section from which hose connections are run to an instrument panel. With this method the pressures caused by the flow of water are determined. The model scale in such tests is generally determined by the pumping capacity of the installation (500 litres per sec. in the present case) and varies between 1:2 and 1:20. The test results are converted in accordance with Froude's model law and used as a basis for the load values in static computation and for determination of the forces to be applied by the hoisting gear.

The margin of error between model tests and tests on full-size installations is about 2 per cent. for pressure measurements and about 5 per cent. for calculation of moments derived therefrom, i.e., within the limits permissible in such measurements.

Hydraulic gates, even if designed to meet all hydrodynamic requirements, are subject to vibration under certain gate lift and overflow conditions because the upstream wall and overflow crest cannot be designed for economical operation at all weir positions and water levels. The unstable forces set up by the flowing water induce vibration in the flexibly supported gates or weir cylinders. If the vibrations thus caused are coupled with the vortices and transitional flow, the unstable forces may be magnified to such an extent that the safety of the structure is affected.

A knowledge of the magnitude of these forces, therefore, is important in order that protective measures may be taken. Information on a range of vibration amplitudes from the perceptibility threshold to the point where the safety of structures is endangered is presented in Fig. 2. This diagram was plotted for turbo-machinery, but may also be adopted for weirs if the vibration-inducing forces set up by the flow of water are substituted for unbalance (Fig. 2).

The vibration-inducing forces acting upon the steel structure have a comparatively low frequency, say 50 cycles per sec. at the most. Several research institutes, therefore, tried to satisfy their requirements with mechanical measuring devices.

The magnitude of the vibration-inducing forces can be determined, with some limitations, from the oscillation equation by measurement of amplitude and damping.

The equilibrium-disturbing forces acting on a vibrating weir are defined by equation (1) with $x$ as the

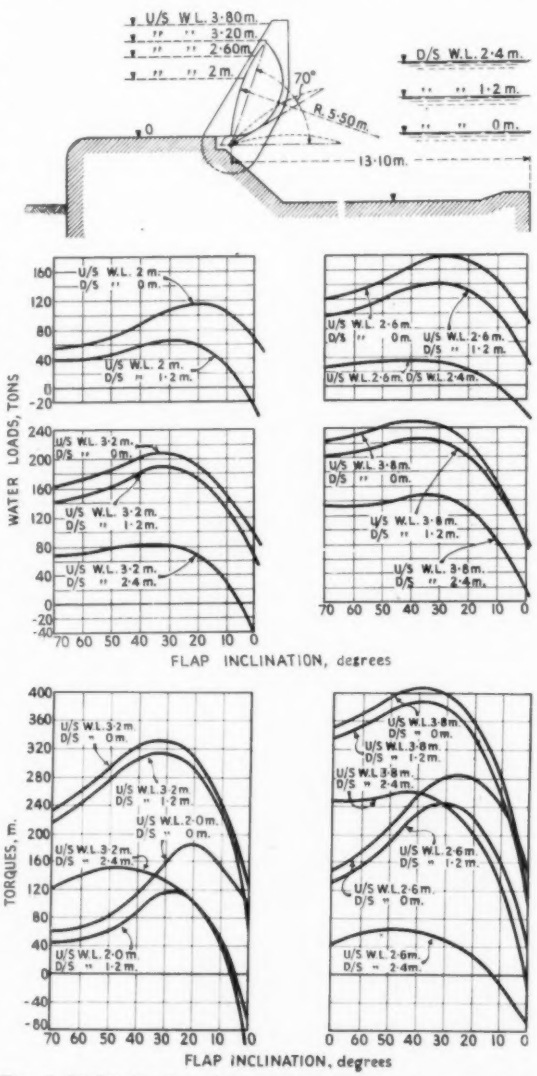

U/S W.L. 3·80m.
" " 3·20m.
" " 2·60m.
" " 2m.
D/S W.L. 2·4m.
" " 1·2m.
" " 0m.
70°
R. 5·50m.
0
13·10m.
WATER LOADS, TONS
U/S W.L. 2m. D/S " 0m.
U/S W.L. 2m. D/S " 1·2m.
U/S W.L. 2·6m. D/S " 0m.
U/S W.L. 2·6m. D/S " 1·2m.
U/S W.L. 2·6m. D/S W.L. 2·4m.
U/S W.L. 3·2m. D/S " 0m.
U/S W.L. 3·2m. D/S " 1·2m.
U/S W.L. 3·2m. D/S " 2·4m.
U/S W.L. 3·8m. D/S " 0m.
U/S W.L. 3·8m. D/S " 1·2m.
U/S W.L. 3·8m. D/S " 2·4m.
FLAP INCLINATION, degrees
TORQUES, m.
U/S W.L. 3·2m. D/S " 0m.
U/S W.L. 3·2m. D/S " 1·2m.
U/S W.L. 2·0m. D/S " 0m.
U/S W.L. 3·2m. D/S " 2·4m.
U/S W.L. 2·0m. D/S " 1·2m.
U/S W.L. 3·8m. D/S " 0m.
U/S W.L. 3·8m. D/S " 1·2m.
U/S W.L. 3·8m. D/S " 2·4m.
U/S W.L. 2·6m. D/S " 1·2m.
U/S W.L. 2·6m. D/S " 0m.
U/S W.L. 2·6m. D/S " 2·4m.
FLAP INCLINATION, degrees

*Fig. 1. Fishbelly flap, 30·5 m. clear width, investigated for different levels and flap positions shown in top diagram; the water loads are indicated by the curves below and the lowermost curves show the torques on the flaps*

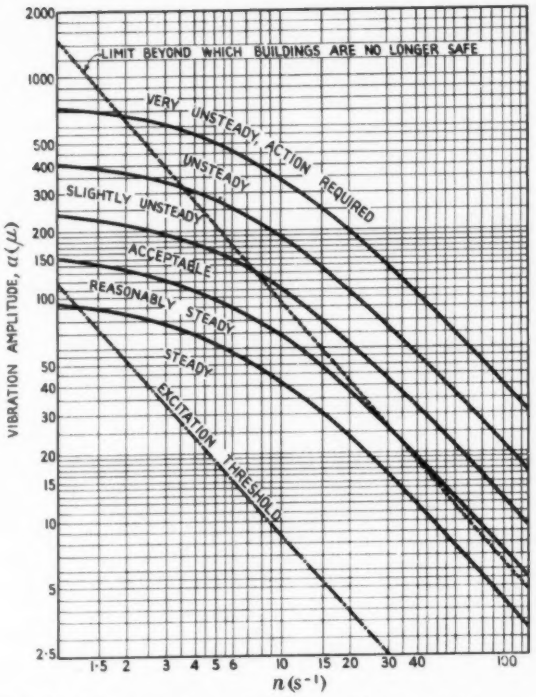



*Fig. 2. Vibration of amplitude ($\mu = {}^{1}/_{1.000}$) of the weir due to vibration-inducing hydrodynamic forces, plotted against the exciting frequency with parameters permitting an apprisal of the weir designs from the vibration aspects*

small deflections from the condition of equilibrium, thus:

$$+m\frac{dt^2}{d^2x}+w\frac{dx}{dt}+cx=P\cos\omega t \qquad \ldots (1)$$

where

$-m\frac{d^2x}{dt^2}$ = force due to acceleration.

$-w\frac{dx}{dt}$ = damping force.

$-cx$ = elasticity.

$+P\cos\omega t$ = oscillatory flow forces acting on the weir (disturbing function).

Weir deflection $x$ can be represented by a general solution of equation (1) to which is added a particular solution corresponding to the disturbing function. If vibrations of equal amplitude are observed for some time, these are accounted for by the disturbing function. The weir undergoes a phase shift $a$ in relation to these oscillatory forces and its motion is thereby defined as

$$x=a\cos(\omega t-\alpha) \qquad \ldots (2)$$

Using this term, the maximum oscillatory hydraulic load derived from measurement of the amplitude $a$ is obtained from the formula

$$P=ma\sqrt{\left(\frac{c}{m}-\omega^2\right)^2+\left(\frac{\omega w}{m}\right)^2} \qquad \ldots (3)$$

The other values required for determination of $P$ in a given weir, besides that of $a$, can be obtained by a free oscillation test. It is true that the mass $m$ includes the mass of water which participates in the oscillation and which cannot be exactly determined either by computation or by test. The same difficulties present themselves with respect to the determination of damping. The results obtained with this method, therefore, are somewhat uncertain, but the method affords the advantage of utmost simplicity.

Messrs. Vibrometer (Fribourg), Askania (Berlin) and Philips (Hamburg), have developed vibration pressure pick-ups which permit pulsating pressure on a weir model to be determined.

Also, very satisfactory results have been obtained by using strain gauges for determining the overall pulsating forces. With this technique, the model is suspended so as to give it freedom of movement in the direction in which oscillation is anticipated. Interposed in the suspension mechanism is a strain gauge and the oscillating forces occurring under conditions of oscillatory water-flow forces are recorded on a measuring bridge or an oscillograph. Measurements are conducted practically without elongation. If it is desired to increase the sensitivity of the test rig, the individual extensometer strips can be glued to a member subjected to bending.*

With this equipment the magnitude of vibration-inducing forces can be very rapidly determined in the

* To achieve an increase in sensitivity, a slight mobility of the model during the test must be taken into account. This arrangement may result in an increase of forces, as shown in Fig. 4.

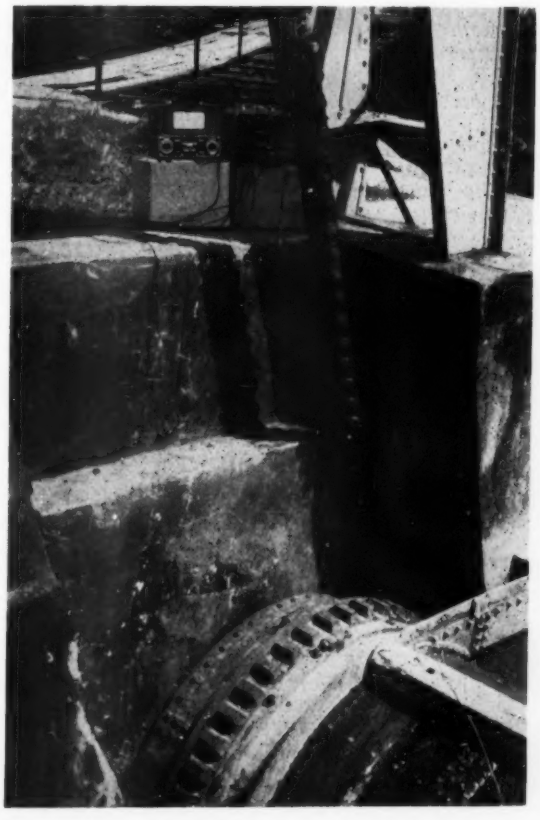


*Fig. 3. Measurement of tractive force in a roller weir chain by means of a Philips strain gauge*

laboratory. If this test is carried out in a flume with glass side walls and if the flow pattern is made visible by addition of silver-bronze to the water, the cause of vibration inducement can be ascertained. A suitable remedy can quickly be found and the reading taken on the measuring bridge will immediately indicate whether or not modifications are successful. Moreover the use of strain-gauge strips permits the measurement of forces in the hoisting-gear chains (Fig. 3) and affords a check on the applicability of model laws and on the correctness of assumed friction values. This is accomplished by measurement of the total tractive force.

Early roller weirs were circular cylinders with an attached small sealing strip which caused the laminar flow to break up under conditions of small gate lift. When these weirs were raised at high water, the periodically generated vortices set up forces acting transversely to the direction of flow which causes vibration. The conventional methods in which pressures transmitted through piezometer holes are indicated on a manometer panel are inadequate for determination of the magnitude of the forces acting on such circular cylinders. Since coupled (hydraulic-elastic) oscillation phenomena play an important role in this field, the unstable forces involved have to be determined in special test installations.

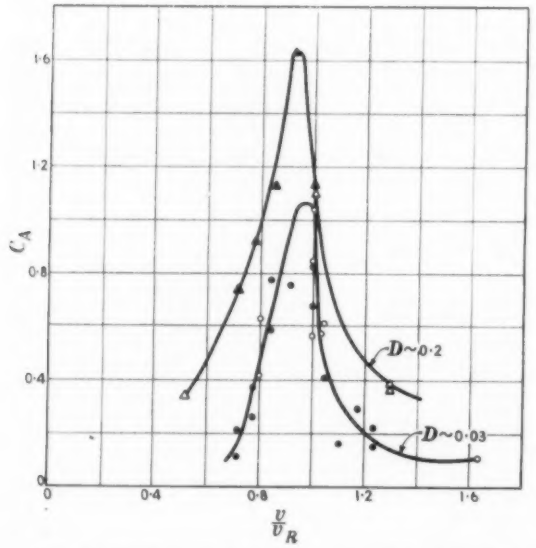



*Fig. 4. Excitation coefficient* cA *as a function of the ratio velocity of flow/resonance velocity*

Cylinders of 0·056 m., 0·1 m., and 0·2 m. diameter were tested in a rectangular enclosed flume with water velocities up to $v=4$ m. per sec. The cylinders were supported in parallel guides outside the water stream. An eddy-current brake permitted rapid change of damping and provision was made for quick change of the masses and springs. The excitation coefficient $C_A$ which, like the lift and drag coefficients of airfoils, was made dimensionless by dividing the maximum exciting force by the static pressure and projected cylinder area, was determined for different degrees of damping and is shown in Fig. 4 as a function of

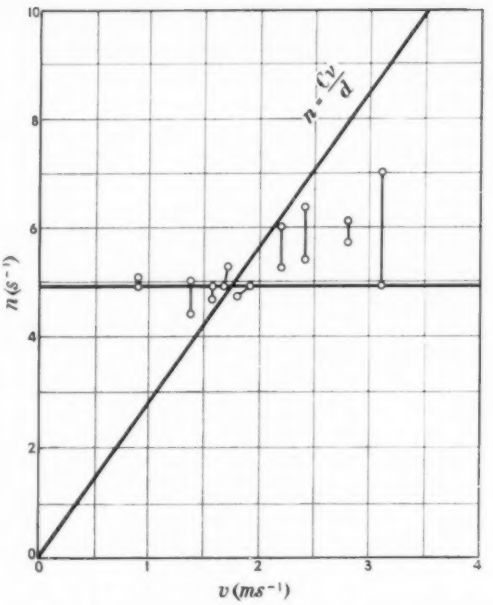



*Fig. 5. Oscillation frequency dependent on velocity of approach*

$\frac{v}{v_R}$, which is the resonance speed and $v$ the velocity of approach of the cylinder in an undisturbed flow.

$$C_A=\frac{P_A}{qF}$$

$$P_A=ma\sqrt{\left(\frac{c}{m}-\omega^2\right)+\left(\frac{\omega w}{m}\right)^2}$$

The amplitude $a$ was recorded by a luminous pointer and the other values ($c$, $m$, $w$) were determined by free oscillation tests in still water.

A factor to be taken into account in these investigations is that self-controlling coupled oscillation sometimes results in a particularly high excitation coefficient which does not always become apparent in later tests conducted with the same layout, because the coupling does not become so effective for some reason or other. Fig. 4, therefore, essentially represents the enveloping curve of the maximum $C_A$ values obtained. This diagram is adequate for the dimensioning of weirs, chimneys, gas-holders and other structures in which knowledge of the maximum load occurring transversely to the wind direction is important. The resonance velocity $v_R$ is obtained from the equation

$$C=\frac{d n_R}{v_R} \qquad \ldots(4)$$

where

$d(m)$ = cylinder diameter.
$n_R(s^{-1})$ = natural frequency of cylindrical object.
$v_R(ms^{-1})$ = velocity of flow under conditions of resonance.
$C$ = constant (Fig. 6).

$C=0{\cdot}2$ $\quad Re=10^4$
$C=0{\cdot}11$ $\quad Re=50$
in coupled oscillation $C=0{\cdot}16$ $\quad Re=$approx. $10^4$

If the cylinder is rigidly supported and a high degree of damping is employed with the result that it

has very limited motion only, this motion is determined by

$$n=\frac{C\,v}{d}$$

On the other hand, if the cylinder can oscillate under conditions of limited damping, due to its elasticity, the velocity range through which vibration at its natural frequency is induced will become much wider. The frequency of vibration is not the natural frequency of the departing vortices, which increase with increasing velocity following a rectilinear pattern expressed by $n=\frac{C\,v}{d}$, but rather through a certain range the natural frequency of the elastic cylinder (Fig. 5). A qualitative explanation of this phenomenon is that the deadwater follows behind the strut thereby causing a circulation which sets up forces acting at right angles to the direction of flow. On this basis, a flexibly mounted strut would oscillate at its natural frequency only at any approach velocity. Tests have shown, however, that this holds true through a limited range only, say 0·5 to 1·7 times

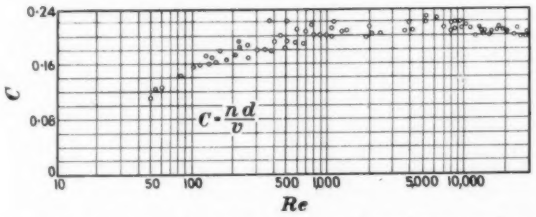



*Fig. 6. Constant C dependent on Renold's number*

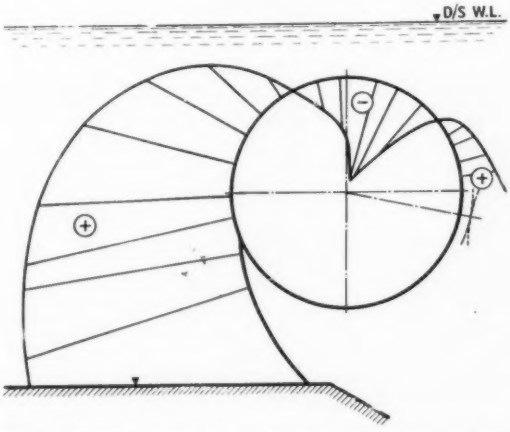



*Fig. 7. Distribution of pressure over a cylindrical weir with a very high overflow*

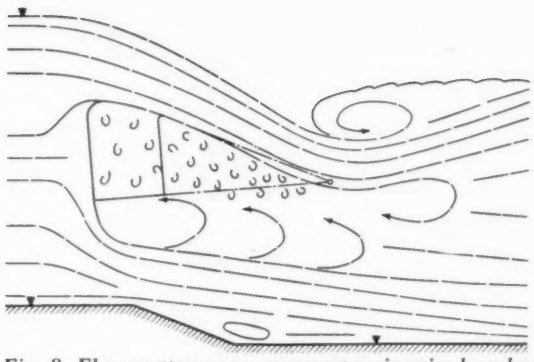


*Fig. 8. Flow pattern on a segment weir raised under conditions of very high flow*

the resonance velocity, with damping conditions occurring in practice and that, as the velocity increases beyond $v_R$, the strut oscillates not only with its natural frequency, but that the vortices also affect excitation and the pattern of motion in accordance with the law expressed by $n=\frac{C\,v}{d}$ (Fig. 5).

In modern cylinder weirs the shield attached to the underside prevents detachment of vortices directly from the cylindrical body. However, if the cylinder weir is designed for a low damming height and there is a considerable overflow under flood conditions, the vacuum at the crest of the cylinder (Fig. 7) will increase with increasing overflow. The deadweight of the cylinder and the friction in the side shield are not sufficient to keep the weir in the static position and the cylinder, being suspended from chains only, will move up. As a result, the vacuum decreases until a condition of equilibrium is reached. The shield which kept the water current away from the cylinder in the lower positions now points forward and periodic vortices will form in the same manner as on the cylinder. With $v=3{\cdot}3$ m. per sec. the periodic forces acting across the direction of flow in the case of a weir of 25 m. length and a cylinder diameter of 3·5 are defined by:—

$$A=C_A\,q\,F\cos\omega t$$

and the moment about the axis of rotation is:—

$$M_d=A\frac{d}{2}=84 \text{ metre tons.}$$

The frequency is

$$n=\frac{C\,d}{v}=0{\cdot}2\,(s^{-1}),\ \omega=2\pi n=1{\cdot}2\,(s^{-1}).$$

The weir cylinder oscillates about its position of equilibrium with a period of $T=5$ s. Seeing that it is loosely suspended from its chain, the restoring forces are practically zero.

$$J\frac{d^2}{dt^2}+w\frac{d\phi}{dt}=M_d\cos\omega t.$$

The amplitude of the up and down movement of the cylinder amounts to $\pm$ 0·3 m. (1 ft.). Moving it out of this oscillating position with the hoisting gear is out of the question since the inevitable result would be chain fracture due to the action of mass forces. The model tests, therefore, have established the fact that a cylinder weir is not suited to such depths of overflow.

A segment weir is much more suitable for operation under the conditions described in the foregoing.

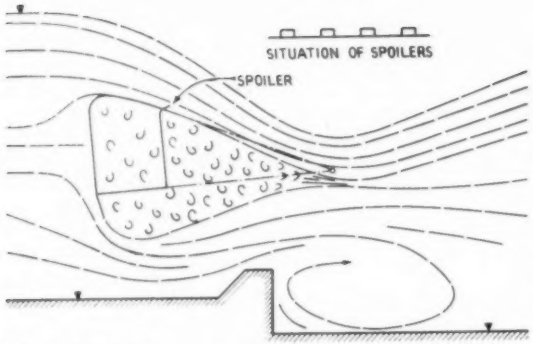



*Fig. 9. Segment weir with spoilers and a bottom sill just downstream of the weir. These expedients eliminated the vibrating-producing vortices shown in Fig. 4*

With an appropriate weir shape and location of the pivotal point of the segment bearing in the pier, self-induced raising of the weir from the closed position can safely be avoided, even under conditions of maximum overflow. However, when the segment gate was raised in the model test under such overflow conditions, the vortices caused by the overflow and underflow induced vibration in the same manner as on the cylinder (Fig. 8). The magnitude of the forces thus generated was such that the test rig was destroyed. The coefficient of the vibration-inducing force rose to $C_A = 1{\cdot}8$. Installation of spoilers 0·3 m. long and 0·3 m. high, which were attached to the end of the flap at an angle of 45° and 0·7 m. from each other, resulted in a slight diminution of forces. As a next step, the cross-sectional area of the river downstream of the weir was somewhat restricted by installing a bottom sill and this prevented the formation of vortices.

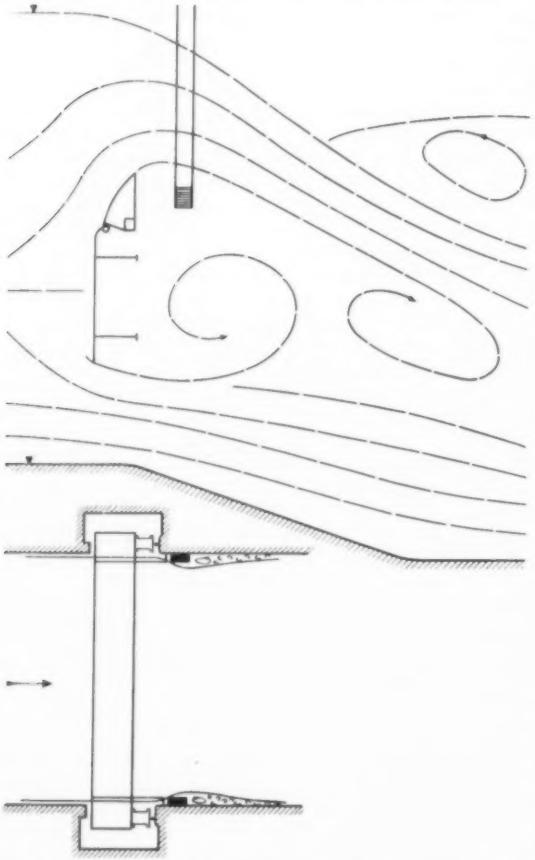


*Fig. 10. Partly raised flap gate under conditions of very high overflow. The turbulence shown in the section was so effectively disturbed by the two spoiler ledges (shown black in the plan) that the vibration-inducing forces were practically eliminated*

The combination of the bottom sill (Fig. 9) and the spoilers succeeded in eliminating the vibration-inducing vortices in the immediate vicinity of the weir, thus reducing the unstable forces to almost the magnitude of the side-shield friction forces. Further investigation with gravel introduced into the river bed showed that a sill of this type does not provoke disturbance due to silting up of the bed. The débris was easily flushed out by raising the weir 10 to 20 cm. for a short time.

A flap gate (Fig. 10), used as a gravel sluice and operated in the weir under identical overflow conditions, was caused to vibrate in a similar manner as the segment gate and roller weir, this being caused by the action of vortices alternately set up by the overflow and underflow with a gate lift of from 2 to 4 m. As this aperture was to be regularly used for the removal of gravel, flotsam and debris, the bottom sill was inappropriate as a vibration-preventing agent.

For this very narrow aperture, therefore, it was suggested that the vibration-inducing vortices in the horizontal plane be broken up by two battens (Fig. 10) attached to the piers. The vortices generated by these battens were orientated along a vertical axis and interefered so effectively with the development vortices along a horizontal axis that the latter no longer exerted dangerous forces on the gate. The residual pulses were less powerful than the friction forces in the side shields. These model tests made it possible to find a remedy for vibration before damage had actually occurred. Work in the laboratory, therefore, proves its worth especially where installations have to meet extraordinary requirements, such as in this particular case of high overflow.

While the cause of vibration described in the preceding sections was periodically formed vortices, a different type of vibration occurs in flap weirs with a limited depth of overflow (5 to 70 cm.). This vibration pattern is also observed with types of flaps on which it has been shown, by measuring the pressure distribution, that the flow is steady and not turbulent. However, vibration is sometimes intensified by the steady flow at the flap breaking up and by poor flap design. In this type of vibration, the water nappe flowing over the weir, the air space below it and the movable elastic flap constitute a coupled oscillating system which extracts so much energy from the falling water that the inherent damping in the system is overcome and constant-amplitude oscillation is produced. Even effective venting of the weir from the sides will not eliminate such vibration, in spite of the fact that it ensures almost perfect static pressure equilibration. The reason is that pressure equalisation with weir

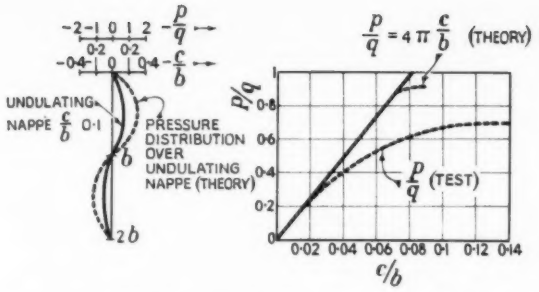



*Fig. 11. Pressure distribution over an undulating water nappe*

flaps longer than 5 m., oscillating at a frequency of the order of 2 to 20 cycles, cannot be accomplished rapidly enough through the lateral openings.

Vibration may become so intensive that, unless appropriate action is taken, the continual dynamic stressing may cause serious damage to the flap and the pulsating air pressure causes vibration in doors and windows over a wide area. In such cases the mechanism of vibration induction is as follows: If the water nappe flowing over the weir undulates due to a minor disturbance, the air acting on the falling nappe produces a pressure differential on the two sides of the nappe which results in amplification of the curvature (Fig. 11). The steeper the undulation pattern, the greater is the change of volume under the weir and the pressure pulse when the undulation fades out in the tail water. Fig. 12 shows a computed undulation pattern and Fig. 13 is a photograph of the nappe contours produced by an oscillating model flap. In addition to recording the flap movement and measuring the pressure below the weir, the time at which the photograph was taken was recorded on a separate galvanometer loop with a photocell. Fig. 13a, therefore, corresponds to the highest and 13b to the lowest flap position. In Fig. 13c the flap on its downward travel just passes through the zero position. The

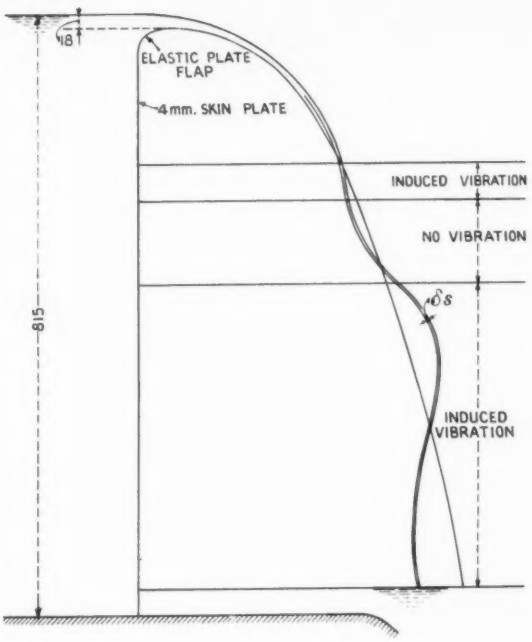



*Fig. 12. Computed undulation of water nappe overshooting weir flap*

flap was made of zinc sheet 0·7 mm. thick and was very flexible. Damping was of a low order. The vibration data are indicated below. If the coupling of flap oscillation with that of the air space is neglected, in order to simplify the problems, it appears that an even pressure pulse, with a peak value of $\Delta p = 1{\cdot}2$ kg./m.$^2$ in the natural frequency of the flap, is sufficient to produce oscillation through the observed angle $\phi_o$ with such a highly flexible flap (Fig. 12).

*(To be continued)*

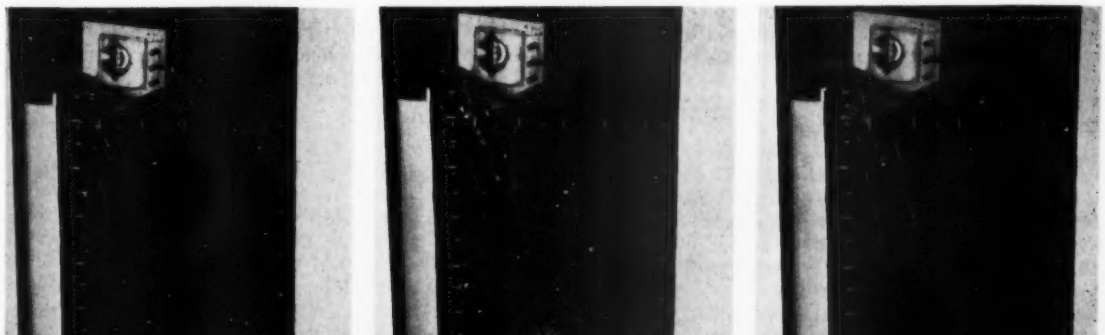


*Fig. 13. Photographs of undulating nappe in different phase positions, the flap moving from its top position through the zero position. The tail water levels at which vibration was observed are shown in Fig. 12*

# The International Union of Geodesy and Geophysics

The Eleventh General Assembly of the I.U.G.G., held in Toronto in September, 1957, was the first major congress of geophysicists to take place after the launching of the International Geophysical Year in July

PART ONE

THE International Union of Geodesy and Geophysics (I.U.G.G.) is a union of seven international scientific associations whose interests extend over nearly all aspects of the physics of the earth: geodesy; seismology and the physics of the earth's interior; meteorology; geomagnetism and aeronomy; physical oceanography; volcanology; and the field which is of greatest interest to water-power engineers, hydrology.

The I.U.G.G. holds its general assemblies every third year, when for a fortnight a large number of formal meetings are held at which progress in the various fields is reported. This year, nearly 1,500 scientists from 57 countries converged on the University of Toronto and, in addition to attending the formal meetings, established or renewed personal contact with other specialists in their own fields, when outstanding difficulties could be resolved or at least clarified and a stimulus provided for further work.

**General Programme**

The topics arousing greatest general interest were in some way connected with the work of the International Geophysical Year (I.G.Y.), the enterprise which, from July, 1957, until the end of 1958, involves approximately fifty national research organisations in international collaboration in the simultaneous observation of world-wide phenomena, such as the changes in the earth's shape; earth tremors; atmospheric circulation; magnetism and its variations; aurora and airglow; solar flares and sun spots; cosmic rays; ocean currents; the changes in glaciers; and radioactivity in the atmosphere. Of particular fascination was the discussion of rockets and satellites which carry instruments to great heights and allow them to circulate around the earth for long periods. Looking back, it seems strange that little notice was taken of the announcement by the Russians that they were ready to launch their first satellite. The United States exhibited a full-size replica of the Vanguard rocket and a model of the spherical satellite in it.

Other discussions outside the Hydrology Association, yet of great interest to hydrologists, concerned such matters as natural and man-made changes in climate. At the symposium on the carbon-dioxide cycle (a deceptively colourless title), it was argued that the increased industrialisation of most areas of the globe and the vast increase in the use of combustion engines would greatly increase the proportion of this gas both in the atmosphere and in solution in the oceans. Additional carbon dioxide in the air would reflect some of the earth's infra-red radiation (heat) back to the ground, so causing a rise in temperature over the globe which would accelerate the melting of the polar ice caps and glaciers, raise the level of the oceans, and so quantitatively modify several terms in the hydrological cycle. Such possibilities give greater significance to the work of air and water sampling and analysis done by I.G.Y. teams all over the world.

The symposium on the water balance of the earth, particularly the papers on evaporation from the oceans (by H. Mosby) and its measurement (by W. C. Swinbank), on the circulation of moisture in the atmosphere (by R. C. Sutcliffe), and on the aridity of a land area (by M. Konček), forms another background study of broad interest. Hydrologists realise with increasing force the necessity for physical studies on the broadest possible basis, and the evaporation part of the hydrological cycle provides a good illustration. Its study involves the principles of the conservation of mass (continuity) and of the conservation of energy (heat balance), the fluid mechanics of the transport of vapour from the water surface into the atmosphere (turbulent diffusion), and directly empirical work (evaporation pans).

Numerous other papers of great scientific interest were presented both before the Meteorology and the Physical Oceanography Associations, and their proceedings, to be published early in 1958, will contain information on rainfall, evaporation, and on some oceanographic subjects directly applicable to the study of great lakes and even, with some modification, to smaller inland waters.

**Hydrology**

The work of the International Association of Scientific Hydrology (I.A.H.) is subdivided into surface water and evaporation, underground water, snow and ice, land erosion, precipitation, and instrumentation studies. The various commissions and committees met simultaneously, and the following account represents a selection of subjects of special interest to the engineering hydrologist.

Professor J. T. Thijsse, in his presidential address to the I.A.H., presented a broad and penetrating picture of scientific hydrology, of its constituent parts—precipitation, evaporation, lakes and rivers, ground water, land erosion, ice, etc.—and of the activities of

its practitioners in the fields of observation, instrumentation, classification, statistics, explanation and prediction. The influence of the application of hydrological work extends into the realm of hydraulic engineering, and the work of I.A.H. was shown to receive notable support from engineers interested in such international activities as the World Power Conference and the Congress of Large Dams, the Navigation Congresses, and the conferences on Irrigation and Drainage, and Hydraulic Research. It was particularly valuable to have the President's framework into which subsequent discussions could be fitted.

**Surface-Water Hydrology and Evaporation**

Professor Thijsse also presented, on the author's behalf, an important paper on the "Use of Electronic Computing Machines to Plan the Nile Valley as a Whole," by the Irrigation Adviser to the Republic of the Sudan, H. A. Morrice. The problem before the countries utilising the waters of the Nile is, clearly, how to control the Nile and its tributaries in such a manner that the largest possible irrigation, domestic and industrial (including power) water supplies are provided in all these countries, that floods are controlled, navigation ensured and, in spite of the heavy load of silt, all structures are given a prolonged useful life. With the excellent body of hydrometric data available, chiefly in the Egyptian Government publications, Morrice and his colleagues set themselves the task of studying the effect on overall supplies of the manifold combinations of the numerous feasible control projects. Basically, his technique is one of inspired trials and checks (the words "trial and error" hardly do justice to the process), and is similar in that respect to many old reservoir studies. Here, however, the process is so complex that the old technique of hand computation would take far too long to enable alternative schemes to be presented for comparison within a reasonable period, say a few years. A high-speed electronic digital computer has the ability of handling in a few minutes large series of numerical data fed into it in the form of punched cards or tape. Use of such a machine has not only enabled the Sudanese engineers to obtain a clear picture of the effect of various reservoir projects on the yields obtainable from the Nile and its tributaries, but has led to certain general conclusions on the relative importance of the various terms in the mathematical representation of the problem. The political value of the possession of a comprehensive pattern of alternative solutions must be enormous, and the ability of a computer speedily to provide a dispassionate description of the hydraulic effects of any new proposal should make it easier to maintain an atmosphere conducive to political agreement. Here is one technique which promises to be of great assistance to water engineers, though they may operate on a smaller scale, who encounter opposition to their projects. It should not be overlooked, however, that no computer can give the results a better quality than that of the basic data which have to be collected over many years.

The section concerned with surface-water and evaporation problems, many of them of vital interest to the designers and operators of hydro-electric and multi-purpose projects, received numerous papers which might be classified into groups, as follows:

(*a*) Historical studies, usually leading to semi-empirical formulae and procedures of great value in the region and in the circumstances for which they have been developed;
(*b*) measurements of the elements of the hydrological cycle and their interpretation;
(*c*) statistical theory and methods;
(*d*) idealisations, with special emphasis on the unit-hydrograph aproach.

The paper of most immediate interest to the operators of hydro-electric schemes is "Methods and Procedures Used in Forecasting Dependable Seasonal Streamflows," by Milton S. Sachs, of the Bonneville Power Administration, who is responsible for forecasting the water household of the Grand Coulee scheme on the Columbia River in the State of Washington, U.S.A. On the basis of past records of monthly flows into the Grand Coulee reservoir, Sachs is able to arrange, for every month during the winter season (October to March), a water supply to the power station which satisfies the requirements of maximum energy output, minimum loss of water by flood spill, and safety against drawing down the volume in storage to a level which would unduly curtail power production. His method is historical and does not appear to use statistical theory to give information on possible extremes—floods or droughts—of a magnitude not so far encountered. The separation of stream flow from ground-water (base) flow, and the analysis of the frequency of discharges above the base flow, show that the operation of this very important power scheme is carried out on the advice of competent hydrologists.

Another successful empirical method was described in the paper "Flood Frequency Relations for Gauged and Ungauged Streams," by Tate Dalrymple, of the Water Resources Division of the U.S. Geological Survey. Data from hydrologically homogeneous regions have been analysed so that the magnitude and frequency of peak flood discharges at any point of any stream in each region may be stated with some confidence, up to the maximum so far observed in the region for the number (usually not large) of sections with continuous gauge records and up to the duration of the records. Dalrymple is careful not to enter into statistical speculations enabling long-period extrapolations to be made. His analysis leads to two curves, one relating the flood peak (expressed as a multiple of the mean annual flood peak) to the recurrence interval, and the other relating the mean annual flood to the catchment area and other characteristics. These two curves, together with data derived from maps, give information from which a magnitude/frequency curve may be drawn.

A study of some of the elements of the hydrological cycle, with an idealisation of the storm rainfall producing floods, is contained in the paper "The Influence on Flood Peak Discharges of Some Meteorological, Topographical and Hydraulic Factors," by P. O. Wolf, of the Imperial College, London. The first part of this paper discusses the variation of rainfall intensity with duration and puts forward a smoothed probability pattern. The second part contains a study, arising out of the analysis of the Lynmouth flood disaster of August, 1952, of the effect of the length of the catchment on the peak flood discharge, and attempts to add to the commonly employed slope factor a refinement, of importance in

areas like Exmoor, which permits the convexity of the component catchments to be taken into account.

The paper "Flood Forecast for the Upper Main, Based on Precipitation Data," by Dr. Wallner, of Würzburg, Germany, describes a method of using precipitation data to yield forecasts of flood from catchment areas of 5,000 sq. miles or less, where the speed of advance of flood waves gives insufficient time to warn the inhabitants of downstream areas. Wallner uses unit hydrographs and recession curves, and makes allowance for the state of the vegetation, for the wetness of the ground at the beginning of the flood-producing storm, and for the rate of melting of the snow cover, checking his assumptions by observation of first flood rise in the rivers.

Jean Rodier, of France, in his paper "The Systematic Use of Elementary Catchments for Hydrological Studies in Underdeveloped Territories," describes some fine work undertaken by French hydrologists in various African areas. Rainfall data are available from many areas and cover periods exceeding 30 years, but in order to study the effects of rainfall, etc., more than 20 experimental catchments are being studied, which have been chosen to give a representative cover of all kinds of climate, of soil and of vegetation. Great care is being taken to check the data from the experimental catchments against observations in surrounding areas, and after only three years of observations Rodier is confident that precise information on ten-year floods on each area is available, with some indication of the magnitude of rarer floods. Moreover, his department has accumulated in a short time sufficient data on the effect of vegetation and cultivation on soil erosion, on evaporation losses, and on the replenishment of ground-water bodies, to enable them to recommend important development schemes with confidence.

The careful study of the water budget of Lake Hefner, a reservoir near Oklahoma City in the United States, is by now well known, and the engineer in charge of that study, G. Earl Harbeck, reported on it in his paper "The Lake Hefner Water-loss Investigations." The purpose of the study was to test meteorological equations for the reservoir evaporation, and the energy-budget method was found to be satisfactory for computing evaporation losses over longer periods (one week or more), whilst two of the mass-transfer equations gave fair approximations to daily evaporation-loss figures. Harbeck also developed a simple empirical equation which gives better agreement with observations, although he was criticised for not using such refinements in his application of mass-transfer equations as, for example, were put forward by F. H. W. Green (whose paper is discussed below). The Lake Hefner study also included a valuable comparison of the performances of four types of evaporation pans.

The first paper to be read was "Measurement of Rainfall, Interception and Evaporation Losses in a Plantation of Sitka Spruce Trees," by Frank Law, the Engineer to the Fylde Water Board in Lancashire. Law has reported before on his forest lysimeter which enables him to measure the rain falling on the canopy of trees, the proportion reaching the ground, and the residual running off. Comparison with the performance of a grass-covered lysimeter nearby and a study of the yield of a whole water-supply catchment with but little forest, over a longer period, indicate that afforestation—at least under the conditions of the experiment—considerably reduces the yield by increasing losses. Several contributions to the very spirited discussion suggested that Law's area was not typical, but no generally acceptable conclusion could be arrived at. A great deal of work is also being done in Germany, on the effect of woodlands on the hydrological cycle, and plans have been made for an international conference to be held there, probably in September, 1959, to study a problem which is of vital interest to all those concerned with preserving the greatest possible share of the rainfall for use by man.

K. Ubell, of Hungary, in "The Water Balance of the Sand Ridge between Danube and Tisza," reports on a basically similar study of a different area, for he is concerned with a sand ridge which has virtually no run-off, either above or below ground. Measurement of precipitation, of surface storage, and of the depth of the water table enable him to compute the evaporation and the soil moisture. He also is concerned with the calibration of evaporation pans, but the chief interest of his study to the engineer lies in its application to the present development in Hungary of important power and irrigation projects.

A detailed study of evaporation pans and of evaporation phenomena in general in French Central Africa, is described in a paper by A. Bouchardeau. For over three years Colorado pans have been observed in areas with various climates. Some of the pans were sunk into the ground, some are afloat in lakes, and some have been filled with growing vegetation. Pan and air temperatures and atmospheric vapour pressures have been related to evaporation, and pan results to observations of evaporation from lakes and from experimental catchments.

An interesting survey of the work done on the same subject in the United States is contained in "Meteorological Aspects of Evaporation Phenomena," by Max A. Kohler, of the Hydrological Service Division of the U.S. Weather Bureau. Kohler is able to show that modification of pan evaporation-loss figures on the basis of meteorological data gives more reliable estimates of evaporation from reservoirs, and advocates the inclusion of the changes in heat storage in the computation of monthly evaporation losses. He is now investigating the application of evaporation studies to river forecasting.

A very promising approach to potential evaporation is described by F. H. W. Green, of the Nature Conservancy (Great Britain), in his paper "Problems Raised by the Operation of, and the Results from, a Small Network of British Evaporation Measuring Stations." These stations consist of a simple version of Thornthwaite's apparatus, and are distributed over places in Great Britain and Ireland which have significantly different climatic régimes. Green has developed an elegant application of Sutton's theory and produced results from which he is able to deduce apparently systematic regional differences in potential evaporation, supporting his belief that potential evaporation is a climatic factor like any other, with a "standard" value for a station comparable, say, to its "standard" screen temperatures. This leads to interesting speculations on the practical application of the potential-evaporation concept to water budgets.

*(To be continued)*

# Cavitation in Turbomachines

In this article, which follows a contribution by Dipl. Eng. F. A. L. Winternitz on the same subject, K. K. SHALNEV, of the Institute of Mechanics, Academy of Sciences, U.S.S.R., places further data at the disposal of water-turbine designers

PART TWO

**Surface Roughness Cavitation**

Surface roughness causing cavitation and erosion can have various forms and can be variously located. Particularly harmful is any roughness on the walls of the runner chamber as it causes rapid erosion[20]. Where any roughness existed it was noticed that rapid erosion developed where the clearance was narrow. This circumstance determined the choice of method used by the writer in investigating surface-roughness cavitation. The investigations may be divided into two groups: (1) investigations in a rectilinear channel, and (2) investigations of walls on which the roughness was created artificially[8,21].

In the first series of tests the models were arranged as shown in Fig. 7*a*. The walls of the working chamber were constructed of glass so that observations could be made and photographs taken of the cavitation area. In the second series of the tests the roughness models were attached to the contracting wall (S27) as shown in Fig. 7*b*.

The characteristics of the models and test conditions are given in Table III. The notations used for these models are also given in Table III:—$a_r$=height of roughness; $v$=flow velocity; $a$=channel height or clearance height; $H_r$=roughness cavitation coefficient; $\lambda=l_{cav}/a_r$ relative length of cavitation, in terms of the roughness height and the Reynolds number (Re).

The test consisted of determining the critical values of $H_r$* and other values of $H_r$, corresponding to different cavitation lengths. High-speed photographs of the cavitation region were taken for certain models. The cavitation coefficient $H_r$ was determined from pressures and velocities in the channel upstream a roughness model.

$$H_r=\frac{p_\infty-p_v}{\gamma q_\infty}$$

The high-speed photographs of the cavitation area in the first series of tests showed that the cavitation region at the initial stages of development consisted of cavities which were periodically formed and carried away by the flow (Fig. 8). The frequency of rupture was of regular character and could be expressed by Strouhal number Sh=0·10 to 0·20 depending on how

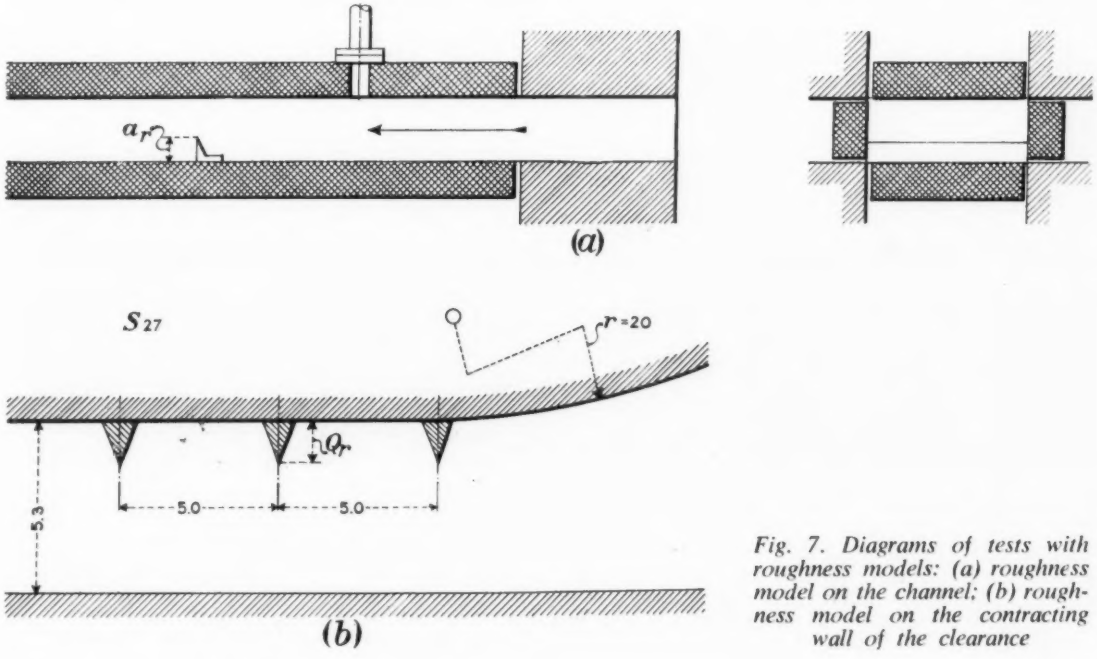



*Fig. 7. Diagrams of tests with roughness models: (a) roughness model on the channel; (b) roughness model on the contracting wall of the clearance*

deeply the roughness peaks were immersed in the boundary layer. If the regularity is observed for very small roughnesses as well, and at the same flow velocity, the number of the cavities torn away per second is inversely proportional to the roughness height. This frequency can reach the value, comparable with the frequencies of oscillators, employed in the tests of the resistance to the accelerated cavitation erosion. As is well known, in tests of this kind almost any material will quickly manifest intensive cavitation erosion.

TABLE III

| Model | $a$ mm. | $a_r$ mm. | $v$ m. sec.$^{-1}$ | $\lambda$ | $H_r$ | Re $\times 10^{-5}$ |
|---|---|---|---|---|---|---|
| T-1 | 24·0 | 6·0 | 5·2–7·4 | 4·5–10 | 2·11–2·57 | 37–53 |
| T-2 | 24·0 | 3·0 | 9·4 | 4·0–6·0 | 1·92 | 33·0 |
| T-3 | 20·0 | 4·5 | 4·0–11·2 | 2·5–19·0 | 0·97–2·23 | 27·0–74·1 |
| T-4 | 10·6 | 3·0 | 3·6–10·8 | 13–15 | 2·11–2·30 | 13·4–40·5 |
| T-5 | 20·4 | 3·0 | 5·6–13·3 | 13–15 | 1·34–1·59 | 17·5–42·8 |
| T-6 | 30·5 | 3·0 | 5·2–11·6 | 0 | 1·94–2·58 | 15·2–35·3 |
| T-6 | 30·5 | 3·0 | 5·2–11·6 | 13–15 | 1·12–1·34 | 15·2–35·3 |
| S-1 | 20·2 | 4·0 | 12·8 | 0 | 1·79 | 58·2 |
| S-1 | 20·2 | 4·0 | 6·0–13·7 | 10–11 | 0·73–0·99 | 27·3–64·0 |
| S-2 | 20·2 | 4·3 | 10·2–13·6 | 0 | 1·71–2·36 | 61·8–84·5 |
| S-2 | 20·2 | 4·3 | 6·9–14·8 | — | 0·88–0·97 | 42·0–92·0 |
| S-3 | 20·2 | 8·0 | 5·2–10·1 | 0 | 3·82–4·40 | 74·3–14·5 |
| S-3 | 20·2 | 8·0 | 5·2–10·1 | 5–6 | 2·84–3·06 | 74·3–14·5 |

Another important conclusion in connection with the roughness tests, is that cavitation bubbles are formed some distance away from the actual projections of the model.

In the tests on the clearance models with rough walls, visual observations were made of the inception and the development of cavitation. It was discovered that cavitation began at $a_r=0{\cdot}6$ and 1·3 mm. and at first it only appeared behind the first two projections. By increasing the height of the projections $a_r$, $H_{cl}$ increased too. As is shown in Table IV, the values of $H_S$* (model S27), approach the values of $H_P$* for the models of type $P$. The absence of cavitation in model S27 with the projections present, when $a_r=0{\cdot}3$, is explained by the boundary-layer effect.

On the basis of these tests and the photographs of the cavitation region, the assumption was made that the cavitation incepted along the axis of vortexes formed past the projections. Employing this assumption and using Bernoulli's equation for the sections before and after the model, where there is a maximum contraction of the channel section by the flow vortex zone, Fig. 9, we have:

$$\frac{p_\infty}{\gamma}+\frac{v_\infty^2}{2g}=\frac{p_c}{\gamma}+\frac{v_c^2}{2g}+h_1+h_1'+h_2 \qquad ...(8)$$

The velocity $v_c$ can be expressed in terms of the velocity $v$, using the coefficient $\alpha=v/v_c=a_c/a$, while $\alpha=\alpha_1 . \alpha_2$ where $\alpha_1=(a-a_r)/a$, $\alpha_2=a_c/(a-a_r)$ and $a_c$ is a contraction in the sectional height of the model. Then from (8) we have:

$$\frac{p_c}{\gamma}=\frac{p_\infty}{\gamma}-\left(\frac{1+\zeta_1'}{\alpha^2}+\zeta_1+\zeta_2-m^2\right)\frac{v^2}{2g} \qquad ...(9)$$

where $\zeta_1'$, $\zeta_1$ and $\zeta_2$ are resistance coefficients due respectively to the contraction of the stream flowing round the top of the projection, and to the frictional loss $m=v_\infty/v$. Substituting $p_c/\gamma$ in (9) accordingly (2), we get the pressure along the vortex axis to be equal to

$$\frac{p_0}{\gamma}=\frac{p_{min}}{\gamma}=\frac{p_\infty}{\gamma}-\left(\frac{2+\zeta_1'}{\alpha^2}+\zeta_1+\zeta_2-m^2\right)\frac{v^2}{2g} \qquad ...(10)$$

TABLE IV

| Order No. | Model | $a$ | $\mu$ | $H_S$* |
|---|---|---|---|---|
| 1 | S27–1 | 0 | 0·95 | 1·40 |
| 2 | S27–2 | 0·3 | — | — |
| 3 | S27–3 | 0·6 | 0·89 | 1·97 |
| 4 | S27–4 | 1·3 | 0·84 | 3·07 |

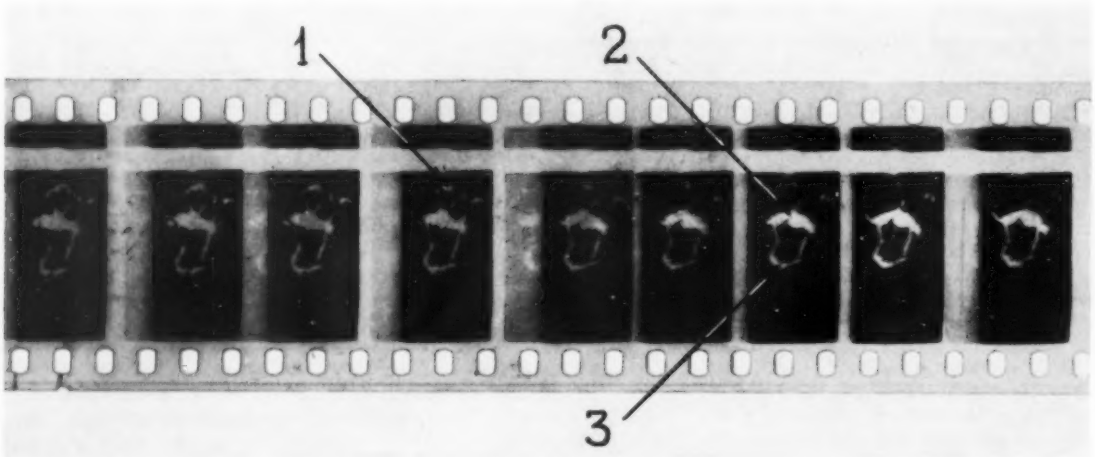



*Fig. 8. Some frames of the high-speed film (3,000–4,000 frames per sec.) of the channel roughness model. Three cavitation vortices are seen: 1. forming, 2. fully developed, 3. decaying*

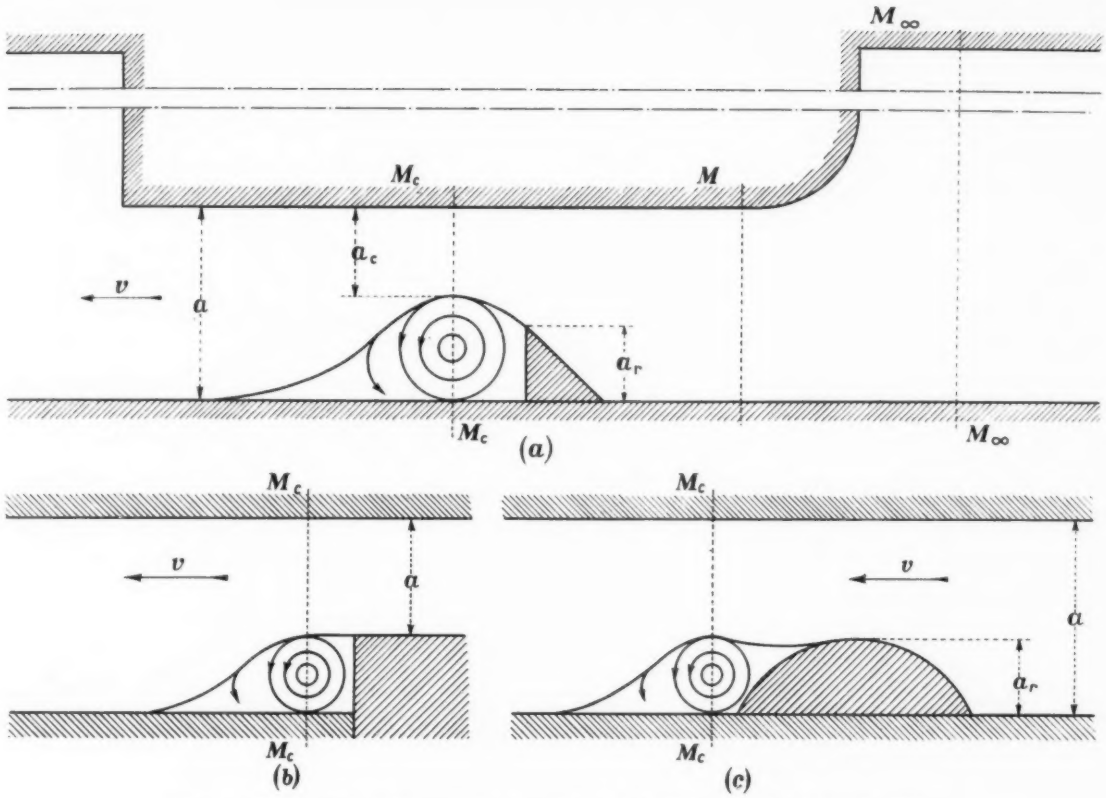



*Fig. 9. Diagrams of flow round roughness for deducing the formula* $H_r^*$

Assuming that $p_{min}=p_v$ at the moment of the cavitation inception, we have from (10);

$$H_S^*=\frac{p_\infty-p_v}{\gamma q}=\frac{2+\zeta_1'}{\alpha^2}+\zeta_1+\zeta_2-m^2 \qquad ...(11)$$

If a roughness is of segment profile, then

$$\alpha_2=1,\ \alpha=\alpha_1$$

and

$$H_S^*=\frac{2+\zeta_1'}{\alpha_1^2}+\zeta_1+\zeta^2-m^2 \qquad ...(12)$$

If the roughness is of step form, it must be supposed that $\alpha_1=1$ and

$$H_S^*=2+\zeta_1+\zeta_2-m^2 \qquad ...(13)$$

In that case, where the cavitation coefficient was determined on the basis of the pressure in the clearance, i.e. according to the first test arrangement with $v=v_\infty$, it should be taken that $m=1$ and $\zeta_1=0$ in formulae (11) to (13). We will then have the following equation for a projection of triangular profile:—

$$H_r^*=\frac{2+\zeta_1'}{\alpha^2}+\zeta_2-1 \qquad ...(14)$$

for segment profile:—

$$H_r^*=\frac{2+\zeta_1'}{\alpha_1^2}+\zeta_2-1 \qquad ...(15)$$

and for a step-form profile:—

$$H_r^*=1+\zeta_1'+\zeta_2 \text{ or } H_r^*=1+\zeta_2 \qquad ...(16)$$

The critical values of $H_r^*$ for the triangular and segment profiles were calculated from formulae (14) to (15), assuming that values of $\alpha$ were known[21]. The results of the calculations are given in the curve $H_r(a_r/a)$ in Fig. 10.

The experimental points of $H_r$, corresponding to different stages of cavitation with various roughness profiles are also shown in Fig. 10. The test values of $H_S^*$, decreased by 1 in accordance with the formulae (11) and (14), for the S27 models are likewise plotted on this graph.

The interdependence of the values of $H_r^*(a_r/a)$ make clear at least one important characteristic of surface-roughness cavitation; that is, with a decrease in the relative height of a projection in clearance channels down to $a_r/a\approx 0$, the coefficients $H_r$ and $H_r^*$ tend, independently of cavitation stage and the form of roughness profile, to approach the maximum value of $H_r=H_r^*=1$, if the tops of the projection jut out beyond the boundary layer.

**Relationship between Profile Cavitation of the Stationary Hydrofoil, Clearance Cavitation and Roughness Cavitation**

Passing from investigations into the separate design elements to the study of cavitation in actual turbomachines, let us first consider possible types of cavitation in a stationary hydrofoil such as a blade-profile model (Fig. 11). It is assumed that the hydrofoil has one of its ends fastened to the water tunnel wall, and between its other end and the opposite wall there is an interval equal to the value of the clearance height *a*.

Further, that in one case the hydrofoil working surface is smooth, and in the other case the suction surface is provided with roughness of one of the types already described. The hydrofoil profile cavitation coefficient is determined by the relation:—

$$H_{pr}=\frac{p_\infty-p_v}{\gamma q_\infty}$$

For the stationary hydrofoil, coefficients for blade-tip clearance cavitation or blade-face cavitation (clearances *P or S*) must be determined by the expression):—

$$H_{cl}=\frac{p_{0,u}-p_v}{\gamma q} \qquad ...(17)$$

where $p_{0,u}$ is the pressure on the upper or lower surface of the hydrofoil near its face end. The choice of an index for $p$ depends on whether $p_u \gtrless p_u$, that is, from what side of the hydrofoil the stream flows through the clearance to the other side.

On the basis of the expression used for the pressure coefficient,

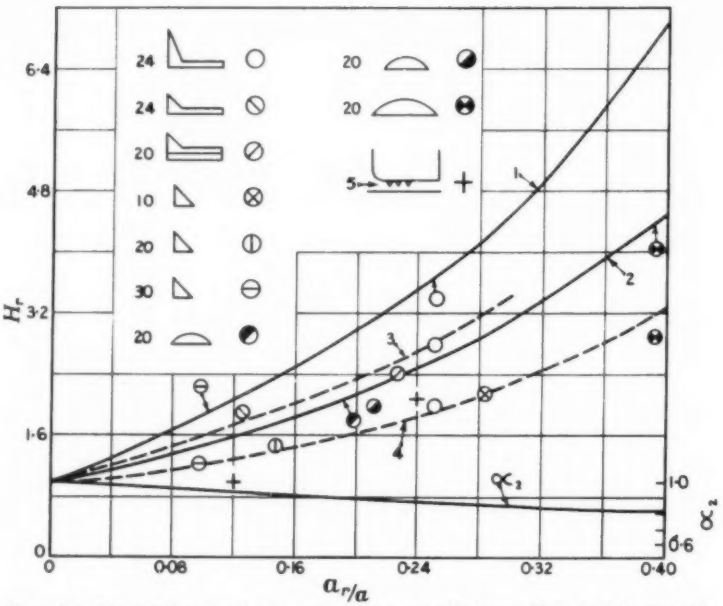



*Fig. 10. Dependence of the cavitation coefficients* $H_r^*$ $(a_r/a)$ *and* $H_r$ $(a_r/a)$ *for the completely developed cavitation* $\lambda=4$–$12$ *on the roughness of various profiles. The full lines 1 and 2 are* $H^*$, *calculated by formulae (14) and (15) at* $\alpha_2$, *shown in the lower part of this graph. The dotted lines are plotted on the basis of the test data: line 3 corresponds to the minimum values of* $H_r$ *at* $\lambda=0$ *and line 4 corresponds to the same value at* $\lambda=4$–$12$

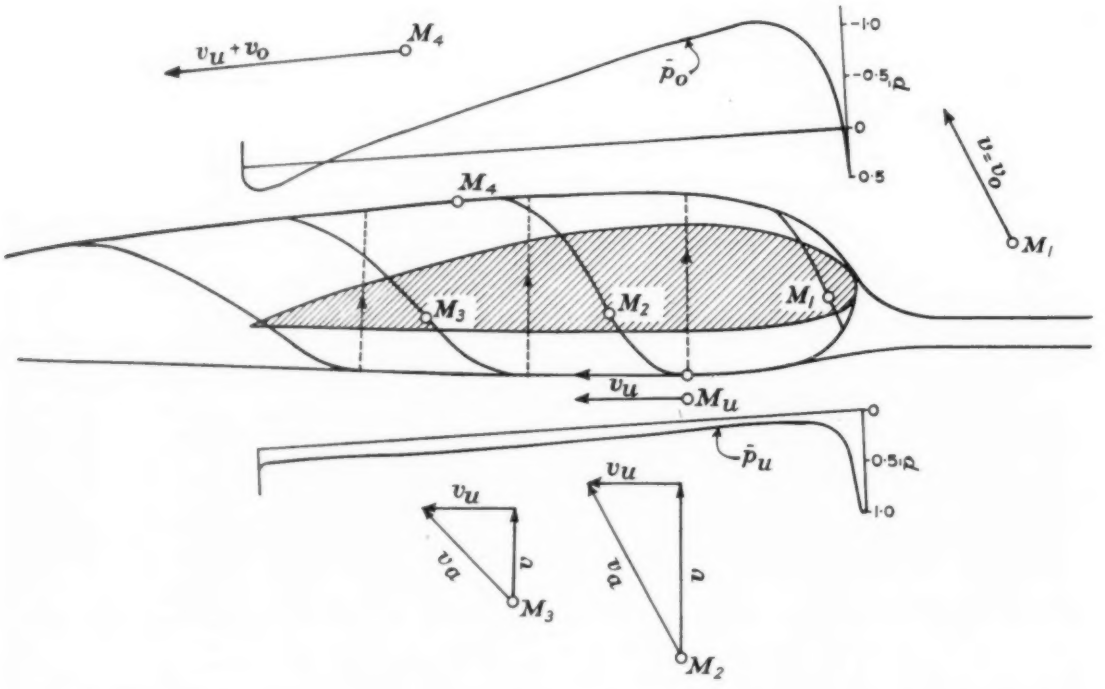



*Fig. 11. Flow through the clearance between the stationary hydrofoil face (hatched area) and the water-tunnel working chamber wall*

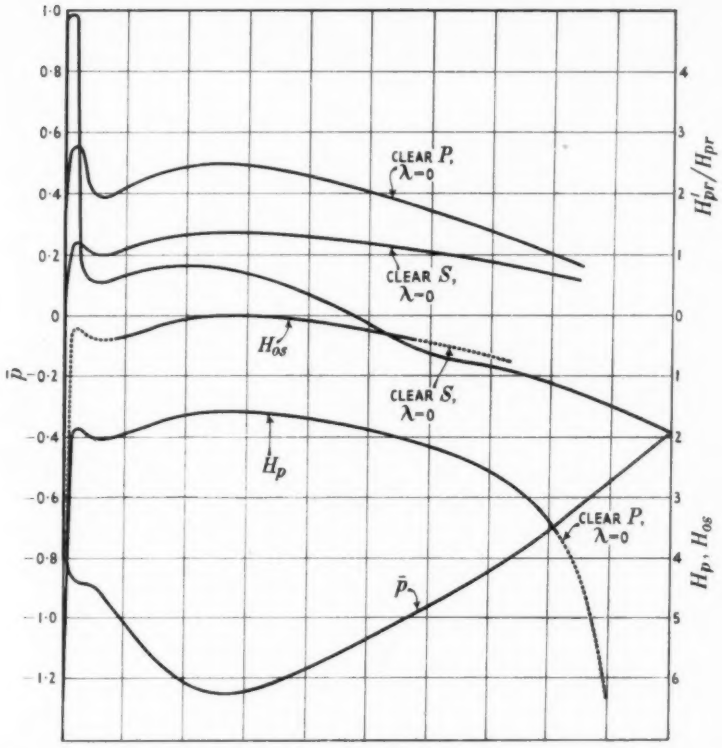



*Fig. 12. Distribution of pressure* $\bar{p}$ *along the profile chord, possible zones of the blade-face cavitation along the profile chord in the case of the clearance* P, *the same zones of the blade-tip cavitation for the case with the clearance* S *and comparison of* $H^{1}_{pr}$, *corresponding to the inception of the blade-face cavitation and tip cavitation with* $H_{pr}^{*} = -\bar{p}_{min}$

pressure distribution along the profile chord is known. For calculations of this kind it may be assumed that $H_{pr} = -\bar{p}_{min}$ and the values of $\phi$ can be taken from the clearance model test data.

Comparing the calculated values of $H_{cl}$ with the critical value of $H_{cl}^{*}$, obtained from the model tests, it is possible to predict the regions where the blade-face or the blade-tip cavitation will occur and where they will be absolutely absent (Fig. 12).

Expression (21), transformed into

$$H_{pr} = H_{cl}\,\phi^2(\bar{p}_{0,u} - \bar{p}_{u,0}) - \bar{p}_{0,u} \quad ...(22)$$

gives the possibility of determining, with a given clearance type and $H_{cl}^{*}$ the value of $H_{pr}$, at which the blade-face clearance cavitation or the blade-tip cavitation should be absent, and also of comparing the anti-cavitation characteristics of clearances of different types (Fig. 12).

The relationship between the profile cavitation coefficient $H_{pr}$ and the surface-roughness cavitation coefficient $H_r$ can be deduced from the following considerations. The pressure in the hydrofoil clearance, if the resistance is neglected, is

$$\frac{p}{\gamma} = \frac{p_{0,u}}{\gamma} - \frac{v^2}{2g} \quad ...(23)$$

$$\bar{p}_{0,u} = \frac{p_{0,u} - p_\infty}{\gamma q_\infty} = 1 - \frac{v_{0,u}^{\,2}}{v_\infty^{\,2}}$$

the pressure can be expressed (as is conventional in the aerodynamics) as:—

$$\frac{p_{0,u}}{\gamma} = \bar{p}_{0,u} \cdot q_\infty + \frac{p_\infty}{\gamma} \quad ...(18)$$

If now, in the equation (17), we substitute $p_{0,u}/\gamma$ for $H_{cl}$, we get:—

$$H_{cl} = \frac{q_\infty}{q}(\bar{p}_{0,u} = \lambda_{pr}) \quad ...(19)$$

The velocity head, in the hydrofoil clearance will be equal to:

$$q = \phi^2 q_\infty(\bar{p}_{0,u} - p_{u,0}) \quad ...(20)$$

where $\phi^2 = 1/(1+\zeta_{cl})$, $\zeta_{cl}$ is a clearance resistance. Having substituted $q$ by its expression (20), we have from (19):

$$H_{cl} = \frac{\bar{p}_{0,u} + H_{pr}}{\phi^2(\bar{p}_{0,u} - \bar{p}_{u,0})} \quad ...(21)$$

By using formula (21), the value of $H_{cl}$ can be calculated for different points of the hydrofoil if the

Replacing the pressure $p_{0,u}/\gamma$ in this equation by its expression in (18), the formula for $H_r$ is converted into:—

$$H_r = \frac{p_\infty - p_v}{\gamma q_\infty} = \frac{p - p_v}{\gamma q} =$$

$$= \frac{q}{q_\infty}(p_{0,u} + H_{pr}) - 1 = \frac{\bar{p}_{0,u} + H_{pr}}{\phi^2(\bar{p}_{0,u} - \bar{p}_{u,0})} - 1$$

where $q$ is substituted by (20). From this formula we have

$$H_{pr} = H_r\,\phi^2(\bar{p}_{0,u} - \bar{p}_{u,0}) - \bar{p}_{0,u} + 1 \quad ...(24)$$

We can now compare the cavitation coefficients $H_{pr}^{*}$ and $H_{pr}^{*\prime}$, the first corresponding to the smooth hydrofoil cavitation, and the second to the cavitation of the hydrofoil having the surface roughened by means of a triangular projection. By introducing the term $p_v/\gamma$ into the energy equation for a stream-line flow around the hydrofoil, we then have:—

$$\frac{p_\infty - p_v}{\gamma} + \frac{v_\infty^{\,2}}{2g} = \frac{p_{0,u} - p_v}{\gamma} + \frac{v_{0,u}^{\,2}}{2g}$$

or

$$(H_{pr}+1)q_\infty = (H_{pr}+1)q_{0,u}$$

$$H_{pr} = H_r(1 - \bar{p}_{0,u}) - \bar{p}_{0,u}$$

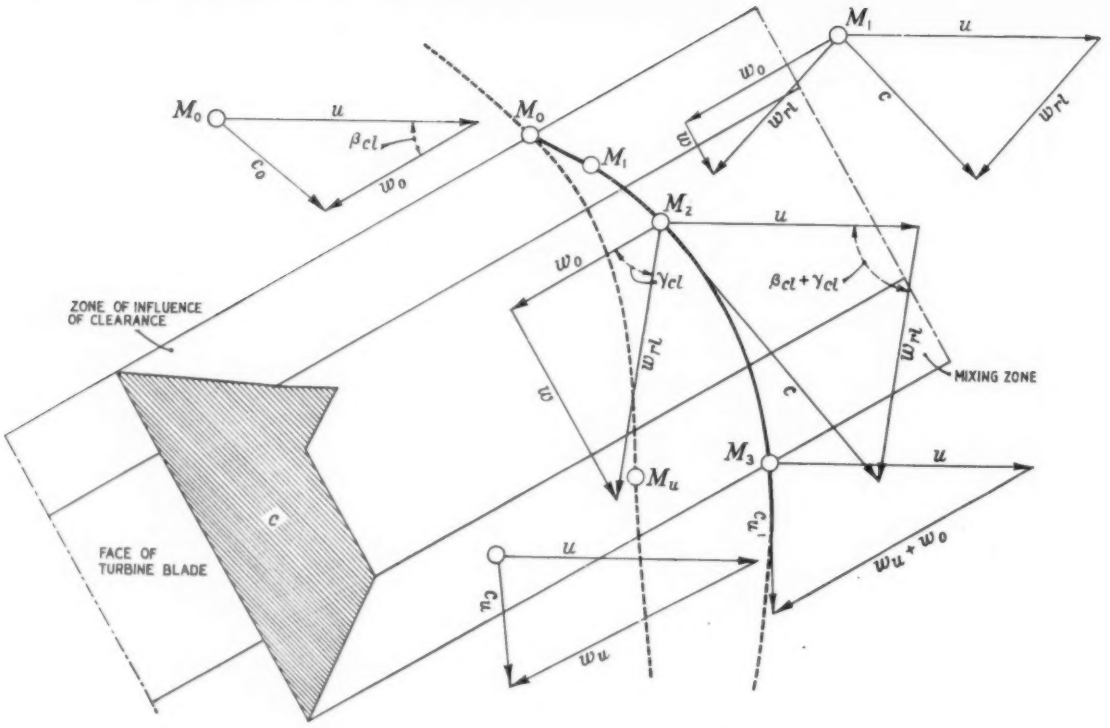



*Fig. 13. Absolute flow through the clearance between axial-turbine blade face and runner casing wall (full line) and through the inter-blade gaps between the casing and the hub (dotted line)*

seeing that by definition $\bar{p}_{0,u}=1-q_{0,u}/q_\infty$.

Let $H_{pr}{}^*=-\bar{p}_{min}$. Consider the difference

$$H_{pr}{}^{*\prime}-H_{pr}{}^*=H_r{}^*(1-\bar{p}_{0,u})-\bar{p}_{0,u}+\bar{p}_{min}$$

which enables one to say which hydrofoil will be more dangerous in respect to cavitation. If $H_r{}^*=1$ and a roughness is situated in the zone of the plus values of $\bar{p}_{0,u}$, $\bar{p}_{0,u}\geqslant 1$, then the value $H^{*\prime}-H^*$ will be negative. This means that the cavitation on the smooth hydrofoil which depends on the profile occurs earlier than the cavitation on the hydrofoil with a rough surface. At $1>\bar{p}_{0,u}\gtrsim 0$ the difference $H_{pr}{}^{*\prime}-H_{pr}{}^*$ may be positive or negative. At $\bar{p}_{0,u}=\bar{p}_{min}$ the value $H_{pr}{}^{*\prime}-H_{pr}{}^*$ will be positive, i.e. the cavitation of the rough surface hydrofoil will occur before the smooth surface hydrofoil cavitation.

**Axial Turbines and Pumps**

Having studied the different types of cavitation of separate design elements and obtained the critical values of the cavitation coefficients, it is possible to analyse the conditions in which any particular kind of cavitation can take place. For this purpose it is necessary to find out the relationship between the critical values of the coefficients of the separate elements and of the machine coefficient, $\sigma$, as a whole. Some preliminary remarks on the parameters, with which we shall deal later, must be made here. The machine setting cavitation coefficient is

$$\sigma=\frac{H_a-H_S-H_v}{H} \qquad \ldots(25)$$

where $H_a$ is the atmospheric pressure; $H_S$ the suction head and $H$ the operating head of the turbine. The coefficient of pressure on the blade is

$$\bar{p}_{0,u}=\frac{p_{0,u}-p_1}{\gamma q_1}$$

where $q_1=w_1{}^2/2g$, $p_1$ is the pressure before the impeller; $w_1$ is the relative velocity of flow entering the impeller; and $p_{0,u}$ is the pressure at any arbitrary point on the blade. The blade-profile cavitation coefficient is

$$H_{pr}=\frac{p_1-p_v}{\gamma q_1} \qquad \ldots(26)$$

The velocity on the profile $w_{0,u}$ is obtained by the expression

$$w_{0,u}=w_1\sqrt{1-\bar{p}_{0,u}}$$

Neglecting the friction and other resistance effects and assuming that the flow through the clearance rotates at a velocity equal to the circumferential velocity at the runner periphery, we have the following velocity vectors for the flow in the blade clearance, (Figs. 13 and 14); the relative velocity in the clearance is:—

$$w=\phi w_1\sqrt{\bar{p}_{0,u}-\bar{p}_{u,0}}$$

the transfer velocity at any clearance section is:—

$$w_{tr}=w_{0,u}$$

the total relative velocity in the clearance is:—

$$w_{rl}=w_1\sqrt{\phi^2(\bar{p}_{0,u}-\bar{p}_{u,0})+1-\bar{p}_{0,u}}$$

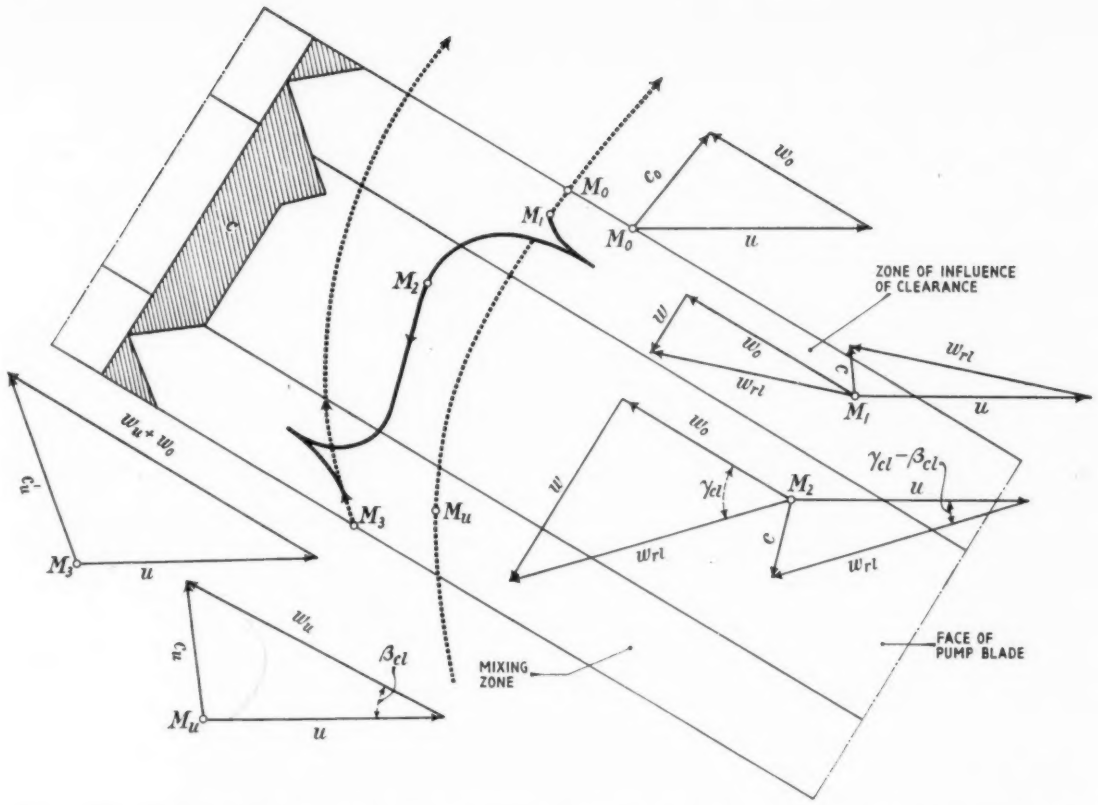



*Fig. 14. Absolute flow through the clearance between axial-pump blade face and impeller casing wall (full line) and through the inter-blade gaps between the chamber and the hub (dotted line)*

The absolute velocity in the clearance in turbines is:—

$$c=\sqrt{w_{rl}^2+u_1^2-2w_{rl}.u_1.\cos(\beta_{cl}+\gamma_{cl})}$$

and in pumps:—

$$c=\sqrt{w_{rl}^2+u_1^2-2w_{rl}.u_1.\cos(\gamma_{cl}-\beta_{cl})}$$

Near the nose of the profile, at the point where $\bar{p}_{0,u}=1$, the direction of the velocity $w_{rl}=w$ coincides with the direction of $w$. We can now determine the relationship between $\sigma$ and $H_{pr}$. By comparing the expressions for the flow energy before and after the turbine runner, and the flow energy past the runner and past the suction tube, we find[7]:—

$$\frac{p_1}{\gamma}=H_a-H_S+\frac{c_5^2-c_2^2}{2g}+\rho H+\frac{c_2^2-c_1^2}{2g}-h_r+H\eta_h=$$

$$=H_a-H_S+\frac{c_5^2-c_1^2}{2g}-h_r+H(\eta_h+\rho) \quad ...(27)$$

where $c_1$ and $c_2$ are absolute velocities at the runner inlet and outlet, respectively; $c_5$ is the velocity at the suction tube outlet; $h_r$ is the turbine runner height and $\eta_h$ is a hydraulic efficiency of a turbine; and $\rho$ means head loss ratio in the suction tube.

Comparing the energy at the pump suction tube inlet section and the energy in the section before the pump impeller, we obtain an expression for the pressure before the pump impeller:—

$$\frac{p_1}{\gamma}=H_a-H_S+\frac{c_0-c_1}{2g}-\rho H \quad ...(28)$$

where $c_0$ is a velocity at the suction pipe inlet.

Substituting the value of $p_1/\gamma$, obtained from formulae (27) and (28), into formula (26) for $H_{pr}$, we find the following relations between the profile cavitation coefficient $H_{pr}$ and the cavitation coefficient $\sigma$.

For turbines this is:—

$$H_{pr}q_1=H_a-H_S-\frac{p_v}{\gamma}+\frac{c_5^2-c_1^2}{2g}-h_r+h_m+H(\eta_h+\rho)$$

or

$$\sigma=\frac{h_r-h_m}{H}-\frac{c_5^2-c_1^2}{2gH}-\eta_h-\rho+H_{pr}\frac{w_1^2}{2gH} \quad ...(29)$$

and for pumps:—

$$H_{pr}q_1=H_a-H_S-\frac{p_v}{\gamma}+\frac{c_0^2-c_1^2}{2g}-\rho H-h_m$$

or

$$\sigma=\frac{h_m}{H}-\frac{c_0^2-c_1^2}{2gH}+\rho+H_{pr}\frac{w_1^2}{2gH} \quad ...(30)$$

Replacing the coefficient $H_{pr}$ in (29) and (30) by its value as expressed in (22), we get the formulae for the relationship between the hydraulic machine cavi-

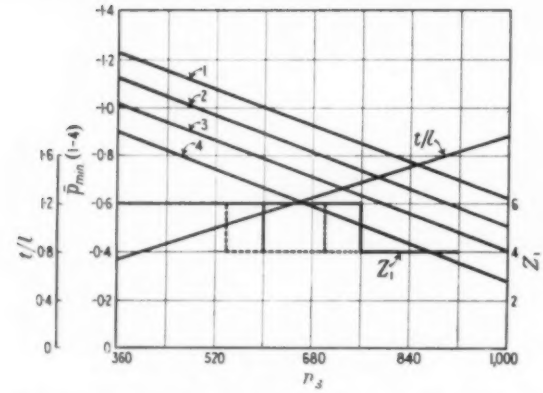



*Fig. 15. Design data curves for hypothetical turbine plotted against* $n_s$: *1, number of blades* $Z_1$ ($n_s$); *2, pitch ratio* t/l ($n_s$); *3, variants of pressure on the blade profile near the face* $p_{min}$ ($n_s$)

tation coefficient $\sigma$ and the clearance cavitation coefficient $H_{cl}$. In turbines this is:—

$$\sigma=\frac{h_r-h_m}{H}-\frac{c_5^2-c_1^2}{2gH}-\eta_h-\rho+$$

$$+\frac{w_1^2}{2gH}[H_{cl}\phi^2(\bar{p}_{0,u}-\bar{p}_{u,0})-\bar{p}_{0,u}] \quad ...(31)$$

and in pumps:—

$$\sigma=\frac{h_m}{H}-\frac{c_0^2-c_1^2}{2gH}+\rho+\frac{w_1^2}{2gH}[H_{cl}\phi^2(\bar{p}_{0,u}-\bar{p}_{u,0})-\bar{p}_{0,u}]$$

...(32)

Now, replacing the coefficient $H_{pr}$ in formulae (31) and (32) by its expression (24) in terms of $H_r$, we establish formulae showing the relationship between the runner chamber wall surface roughness cavitation coefficient $H_r$ and the cavitation coefficient $\sigma$. In turbines this is:—

$$\sigma=\frac{h_r-h_m}{H}-\frac{c_5^2-c_1^2}{2gH}-(\eta_h+\rho)+(H_r q_c+q_w-\bar{p}_{0,u}q_1)\frac{1}{H}$$

...(33)

and in pumps:—

$$\sigma=\frac{h_m}{H}-\frac{c_0^2-c_1^2}{2gH}+\rho+(H_r q_c+q_w-\bar{p}_{0,u}\cdot q_1)\frac{1}{H}$$

...(34)

where $q_c=c^2/2g$ and $q_w=w^2/2g$.

In order to avoid cavitation of all these types, it is required that the unit coefficient $\sigma$ should be equal to or exceed the right parts of equations (29, 30), (31, 32) and (33, 34), calculated on the basis that $H_{pr}=H_{pr}^*$, $H_{cl}=H_{cl}^*$ and $H_r=H_r^*$ or $\sigma\geqslant\sigma_{pr}^*$, $\sigma\geqslant\sigma_{cl}^*$ and $\sigma\geqslant\sigma_r^*$.

As an example of a calculation using the formulae relating to $\sigma^*$ values, corresponding to the inception of different types of cavitation in a turbine, the writer gives the results for a hypothetical machine having a diameter $D_1=6{\cdot}0$ m. For this purpose we shall suppose a turbine, with the rated hydraulic performance data shown in Figs. 15 and 16, in relation to the specific speed coefficient $n_S$. These graphs are plotted on the basis of data which have appeared in various technical publications[7]. They reflect tendencies in the Kaplan-type turbine development. The writer considers that their use in the calculations of $\sigma^*$, corresponding to different types of cavitation in turbines, should enable, at least qualitatively, the predominant influence of any parameter on $\sigma^*$ to be determined.

The values of $\sigma_{pr}^*$ are calculated on the assumption that $H_{pr}^*=-\bar{p}_{min}$. Four variants of $\bar{p}_{min}(n_S)$ are given for $\bar{p}_{min}$, Fig. 15. To calculate $\sigma_{cl}^*$ the values of $H_p^*$ and $H_S^*$ were taken to be equal to 3·75 and 1, respectively. It was assumed that the blade face in the region of $\bar{p}_{min}$ area of the blade suction side should be considered as the most

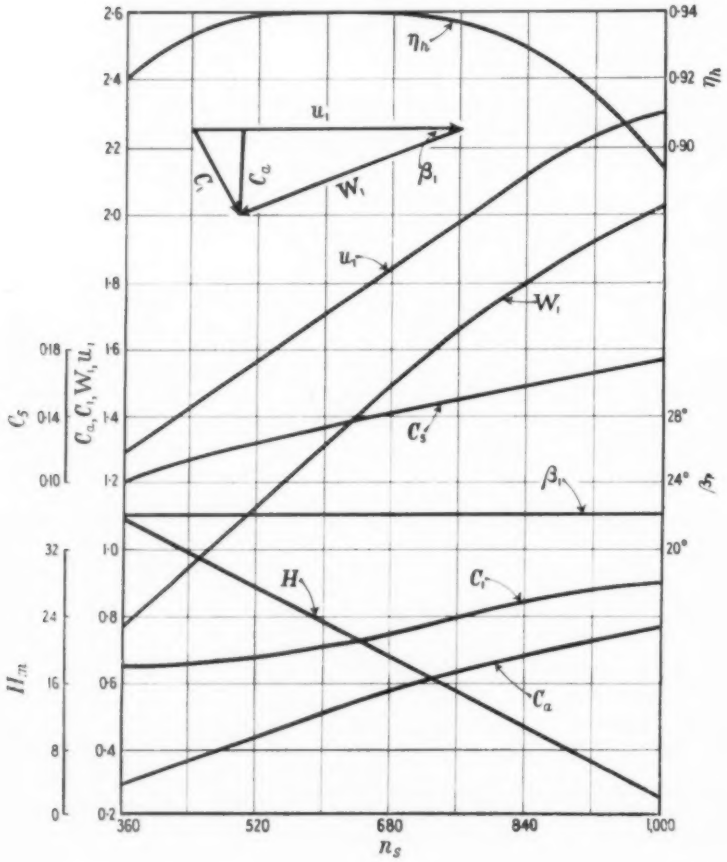



*Fig. 16. Design data curves for hypothetical turbine plotted against* $n_S$: *1, hydraulic efficiency* $\eta_h$ ($n_S$); *2, head* H ($n_S$); *3, inlet flow angle* $\beta$ ($n_S$); *4, velocity coefficient* $U_1=\frac{n}{\sqrt{2gH}}$, $W_1$, $C_1$, $C_a$, *and* $C_5$ ($n_S$)

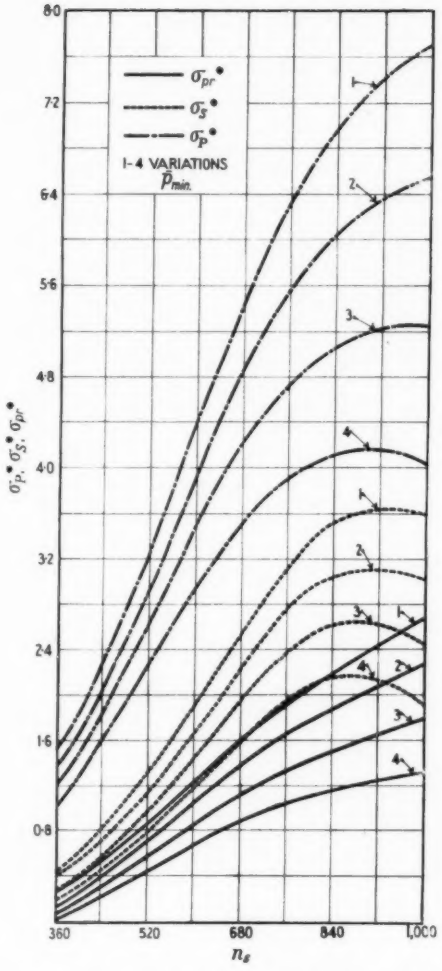



*Fig. 17. Critical values of the cavitation coefficient for hypothetical turbine plotted against* $n_s$: *1,* $\sigma_{pr}^*$ ($n_s$) *with blade-profile cavitation; 2,* $\sigma_P^*$ ($n_s$) *with blade-face cavitation for type* P *clearances; 3,* $\sigma_S^*$ ($n_s$) *with blade-tip cavitation for type* S *clearances*

dangerous with respect to blade-face and blade-tip cavitation. To simplify the calculations it was assumed for the pressure side of the blade that $\bar{p}_0=0{\cdot}1$. For $\sigma_r^*$ calculations it was assumed that $H_r^*=1$. Two variants of $\sigma_r^*$ were worked out. From the comparison of the graphs of $\sigma^*(n_S)$ Figs. 17 and 18, the following conclusions can be reached:—

1. The most unpleasant type of cavitation is that caused by chamber-wall roughness, and to prevent this type of cavitation it is necessary to set the impeller at a greater depth, if the increase of $\sigma$ is to be used as a protective measure. In this respect the cavitation types may be considered in the following order:—blade-face cavitation, blade-tip cavitation and the blade-profile cavitation.

2. In view of purely economic considerations it is often recommended that $\sigma<\sigma^*$ should be adopted. Such practice, however, causes rapid erosion if other measures are not provided.

3. One of these measures is to provide a high finish

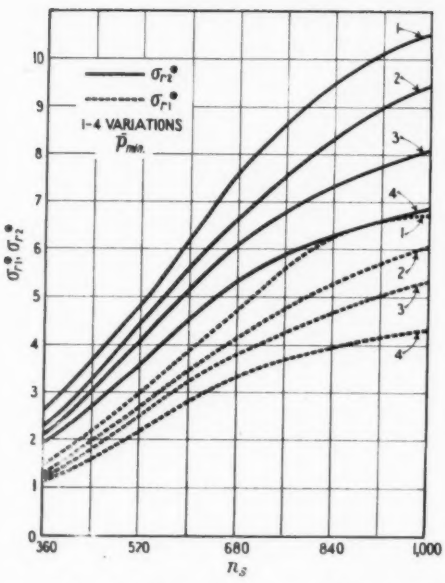



*Fig. 18. Critical values of the cavitation coefficient for hypothetical turbine plotted against* $n_s$: *1,* $\sigma_{r1}^*$ ($n_s$) *with runner casing wall surface-roughness cavitation for type* S *clearances; 2,* $\sigma_{r2}^*$ ($n_s$) *with runner casing wall surface-roughness cavitation for type* P *clearances*

to the surfaces affected by erosion, and to see that the blades are so shaped as to secure a smooth streamlined flow around them with a uniform pressure distribution over the surfaces.

In conclusion the writer would like to point out that further progress in modern hydraulic machinery engineering depends on how much scientists will achieve success in studying the separate type of cavitation met with in hydraulic machines. The hydromechanical conditions in which cavitation is incepted must be studied in relation to its dependence on constructional shapes of the separate parts in which the cavitation occurs, and the effect of these conditions on the value of the machine setting $\sigma$. In this respect the investigations of both separate elements of design and of a hydraulic machine as a whole will be useful.

---

**Imatran Voima Osakeyhtiö** (Imatra River Power Co. Ltd.) have sent us a handsome brochure, printed on art paper and abundantly illustrated, which describes the progress they have achieved since their foundation in 1932, together with affiliated concerns. Following the development of the Imatra River, the Company, which owned 68% of the water resources of the Oulu River, combined with other owners of water rights to launch the Oulojoki Oy., whose achievements have been reported in WATER POWER, May 1956, p. 202. A further company, Kemijoki Oy., in which Imatran Voima participate for 35% of the capital, is developing the resources of the Kemi River, still further north. Imatra Voima Oy. is more or less a nationalised enterprise, 53% of the capital having been subscribed by the Finnish Government, and the rest of the shares being in the hands of the National Pension Institution. An English summary of the Finnish text appears at the end of the brochure.

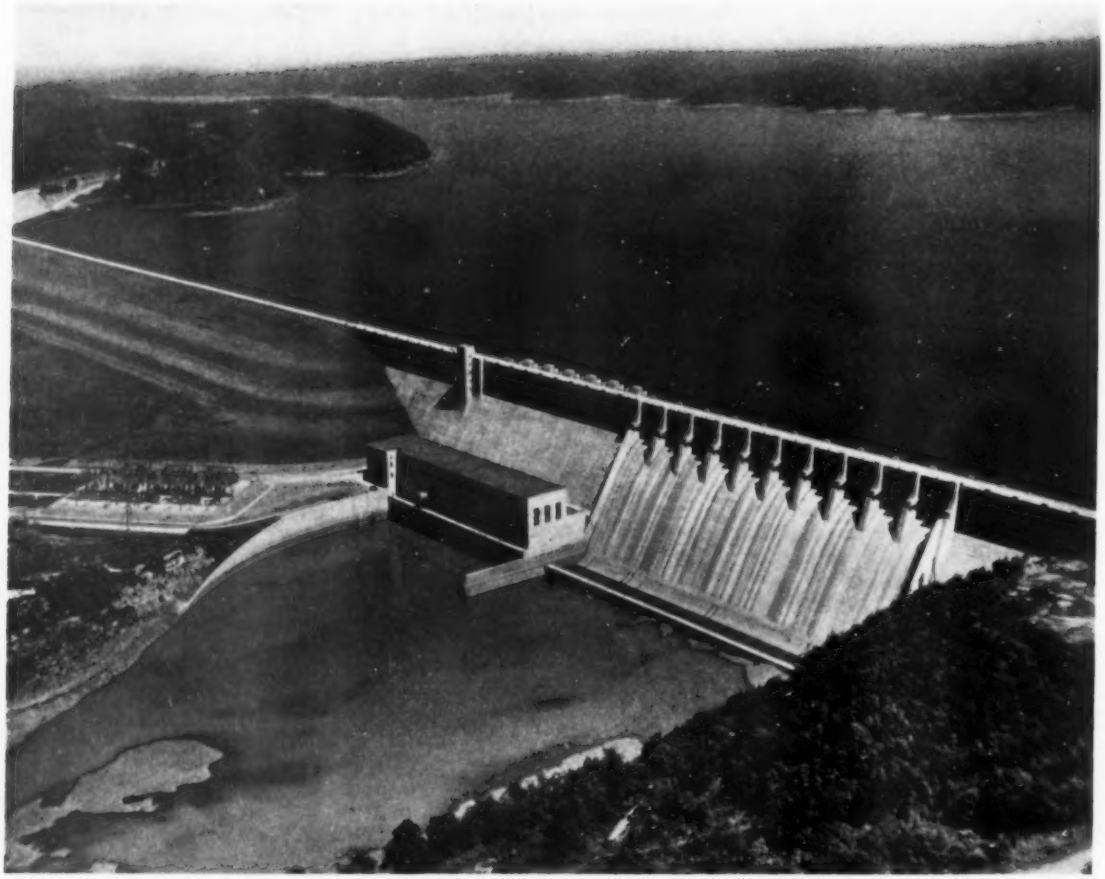


*Fig. 1. Wolf Creek dam and power house, Kentucky*

# Cumberland River Scheme

Brief particulars are given of the various hydro-electric projects on this river

By JOHN GRINDROD, B.A.(Com.)

ESTIMATED, when completed, to provide a power plant capacity in excess of one million kW and to produce an average annual output of approximately 3,500 million kWh, the development of the water resources of the Cumberland River Valley represents a major step in the continued economic advancement of this region of the United States.

It was initially planned solely in the interests of navigation, but by later Acts of Congress the scheme was converted into a large multi-purpose development for exploiting the river's hydro-electric power potential, the control of floods, the further improvement of navigation facilities, the expansion of recreational opportunities, pollution abatement and related features. Apart from local protection projects, which are to some extent locally financed, the total cost of the programme is estimated at $626,461,000, and the scheme involves no fewer than eleven major projects and four head-water projects. Some of these have already been completed, others are under construction, while several are still in deferred status. The four projects in the head-waters above Wolf Creek are included in the long range plans and will probably be recommended for construction after the downstream projects of higher priority have been completed.

Those projects that have been completed and are in full operation for power production, flood control and stream-flow regulation comprise the Wolf Creek,

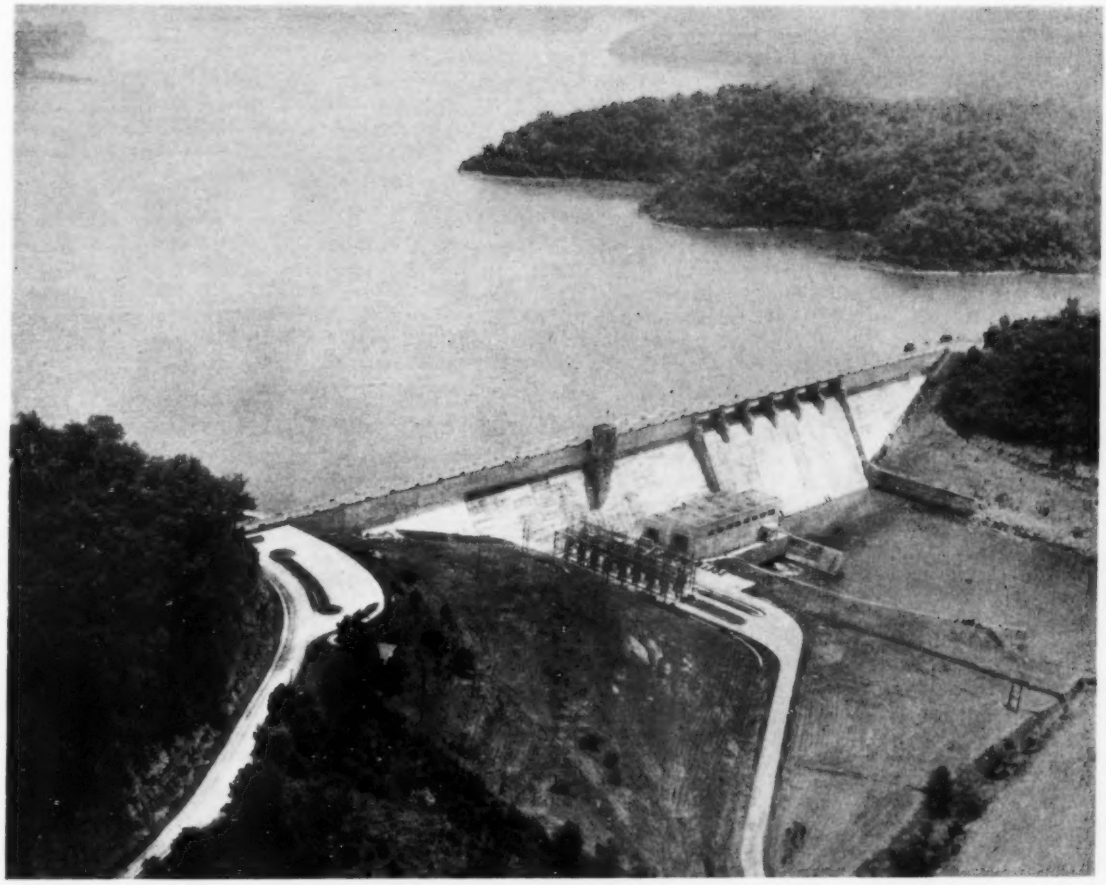


*Fig. 2. Dale Hollow project, Obey River, Tennessee*

Center Hill and the Dale Hollow plants. The construction of the Old Hickory project is now in an advanced stage and initial power production was begun in April 1957; full plant operation will begin shortly. Construction of the superstructure of the Cheatham project power plant has been begun and initial power production is scheduled for the spring of 1958, the plant to be completed in the autumn of this year. The Barkley project is in the early constructional stages. Of those projects which are pending, the planning of the Carthage and Celina projects has now been deferred, as also has work on the Stewarts Ferry project, which will be restudied for economic justification in view of the effect the reservoir may have on a local airfield base. The Three Islands and Rossview projects will also be completely restudied for economic justification before construction begins.

The Wolf Creek project was completed in August 1952, when the last of its six power generating units was put on line. Its combined rolled-earth embankment and concrete gravity dam is approximately 5,736 ft. in length and has a maximum height of 258 ft. from the foundation level to the roadway at crest level. At maximum controlled operating level (top of gates), the reservoir covers an area of 63,530 acres and is 101 miles in length. At the top operating level (spillway crest), the reservoir covers 50,250 acres and has a total storage capacity of 6,089,000 acre ft. The spillway has a discharge capacity of 541,000 cusecs, and is of the concrete gravity, ogee-type having a total width between spray walls of 590 ft. and a net width of 500 ft. It is provided with ten tainter crest gates measuring 37 ft. × 50 ft. and has a bucket-type stilling basin.

In the power intake section, the water is delivered to the power house through six penstocks, 20 ft. in diameter; the maximum net operating head at full flood control level is 214 ft.; average for power 160 ft.; and minimum, with full drawdown, 111 ft.

In the reinforced concrete power house, which is 442 ft. long, 138 ft. wide and 80 ft. high above generator floor, six 45,000 kW generating units are installed, giving a total installed capacity of 270,000 kW. The estimated minimum continuous prime power is 47,000 kW and the total average yearly energy output is estimated at 867 million kWh. The General Electric generators each have a rating of 50,000 kVA and a guaranteed efficiency at full load, 90 per cent. power factor, of 97·2 per cent. The thrust bearings are of the General Electric spring type, while the main exciters are of 290 kW capacity and the pilot exciters 12 kW capacity, both operating at 250 V.

Manufactured by the Baldwin-Lima-Hamilton

Corporation, the Francis type hydraulic turbines, spaced at 58 ft. centres, each have a rated capacity, at 160 ft. head, of 62,500 h.p. and a guaranteed efficiency of 90 per cent. Each discharges 3,750 cusecs at full generator rating, giving a normal speed of 105·9 r.p.m. The turbine governors are of the oil pressure, actuator type.

The ten transformers are 30,000/37,500 kVA, single-phase, 13·2/173 kV, while the circuit breakers are rated 161 kV, 1,200 amp., 3,500,000 kVA interrupting capacity. At the power station switchyard, power is delivered to the TVA at 161,000 V.

The Center Hill project on the Caney Fork River was begun in March 1942 and the construction of its power plant was completed in November 1951. The electrical generating machinery installed in this station was similar in type, rating and manufacture to that installed at the Wolf Creek plant, but there are only three units, giving a total installed capacity of 135,000 kW and an estimated total average yearly energy output of 351 million kWh. There are ten 15,000/20,000 kVA, single-phase, 13·2/161 kV transformers and four 10,000/13,333 kVA single-phase, 13·2/46 kV transformers, together with eight 161 kV, 1,200 amp., 3,500,000 kVA, interrupting capacity circuit breakers and four 46 kV, 600 amp., 1,000,000 kVA interrupting capacity circuit breakers. Power is delivered to the TVA at 161,000 V and 46,000 V.

This project also comprises a rolled-earth embankment and a concrete gravity section. The dam is about 2,160 ft. in length and has a maximum height of 250 ft. At gate-crest level, the area of the reservoir is 23,060 acres and it has a total storage capacity of 2,092,000 acre-ft. About half-a-mile east of the main dam there is a rolled-fill saddle dam with a crest length of 770 ft. and a height of 125 ft.

The ogee-type spillway has a discharge capacity of 458,000 cusecs and incorporates eight tainter crest gates each 37 ft. high and 50 ft. wide. There are six conduits in the spillway section with gates similar to those at Wolf Creek, while in the power intake section there are three 20 ft. diameter penstocks, through which water is delivered to the power station at a maximum operating head (full flood control level) of 207 ft. The average operating head for power is 160 ft. and the minimum, with full drawdown, is 131 ft.

The No. 3 and last of the power generating units at the Dale Hollow project on the Obey River went into production in November 1953. Construction of the 1,717-ft. long, 200-ft. high concrete gravity-type dam was started in 1942 but delayed through the war. The reservoir has a total storage capacity of 1,706,000 acre-ft. and at maximum controlled operating level covers an area of 30,990 acres. The spillway is also of the concrete gravity, ogee type, and has a net width

*Fig. 3. Old Hickory project, Cumberland River*

TABLE I.—PERTINENT DATA, CUMBERLAND RIVER BASIN RESERVOIR PROJECTS

| Projects | Estimated cost | Funds available through FY 56 | Funds Appropriated FY 57 | Dam | | Max. Pool Elev. | Min. Pool Elev. | Reservoir area (acres) | Reservoir capacity (acre-ft.) | Reservoir length (miles) | Shore line (miles) | Power plant capacity (kW) | Avg. net power head (ft.) | Est. avg. annual energy output (kW-hrs.) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Max. height (ft.) | Length (ft.) | | | | | | | | | |
| Dale Hollow | 25,961,000 | 25,961,000 | — | 200 | 1,717 | 663 | 631 | 30,990 | 1,706,000 | 61 | 620 | 54,000 | 140 | 127,000,000 |
| Center Hill | 44,330,000 | 44,330,000 | — | 250 | 2,160 | 685 | 618 | 23,060 | 2,092,000 | 64 | 415 | 135,000 | 160 | 351,000,000 |
| Wolf Creek | 79,080,000 | 79,080,000 | — | 258 | 5,736 | 760 | 673 | 63,530 | 6,089,000 | 101 | 1,255 | 270,000 | 160 | 867,000,000 |
| Stewarts Ferry | 23,400,000 | 380,600 | 10,000 | 146 | 2,704 | 507·5 | 472 | 25,220 | 723,000 | 42 | 270 | 13,500 | 90 | 52,000,000 |
| Three Islands | 21,900,000 | 111,900 | — | 142 | 3,800 | 503 | 456 | 14,560 | 715,000 | 42 | (1) | 18,000 | 87 | 54,000,000 |
| Rossview | 12,590,000 | 6,800 | — | 152 | 3,850 | 481 | 410 | 9,400 | 372,000 | 42 | (1) | — | — | — |
| Cheatham | 30,300,000 | 24,965,500 | 2,900,000 | 75 | 800 (2) | 385 (3) | 382 | 7,450 | 104,000 | 68 | 320 | 36,000 | 22 | 160,000,000 |
| Barkley | 167,000,000 | 275,800 | 1,100,000 | 130 | 7,785 (2) | 375 | 354 | 96,000 | 2,248,000 | 118 | (1) | 130,000 | 44 | 600,000,000 |
| Old Hickory | 47,600,000 | 44,646,200 | 2,250,000 | 98 | 3,605 (2) | 450 | 442 | 27,450 | 545,000 | 97 | 560 | 100,000 | 45 | 420,000,000 |
| Carthage | 40,000,000 | 177,100 | — | 98 | 1,258 | 508 | 497 | 15,000 | 355,000 | 72 | (1) | 92,000 | 40 | 310,000,000 |
| Celina | 34,300,000 | 133,100 | — | 86 | 2,298 | 555 | 549 | 13,150 | 248,000 | 75 | (1) | 69,000 | 38 | 227,000,000 |
| Four headwater projects | 100,000,000 | — | — | — | — | — | — | — | — | — | — | 95,000 | — | 360,000,000 |
| TOTAL | 626,461,000 | 220,068,000 | 6,260,000 | | | | | | | | | 1,012,500 | | 3,528,000,000 |

(1) Not yet determined.
(2) Exclusive of lock section.
(3) Normal operating level.

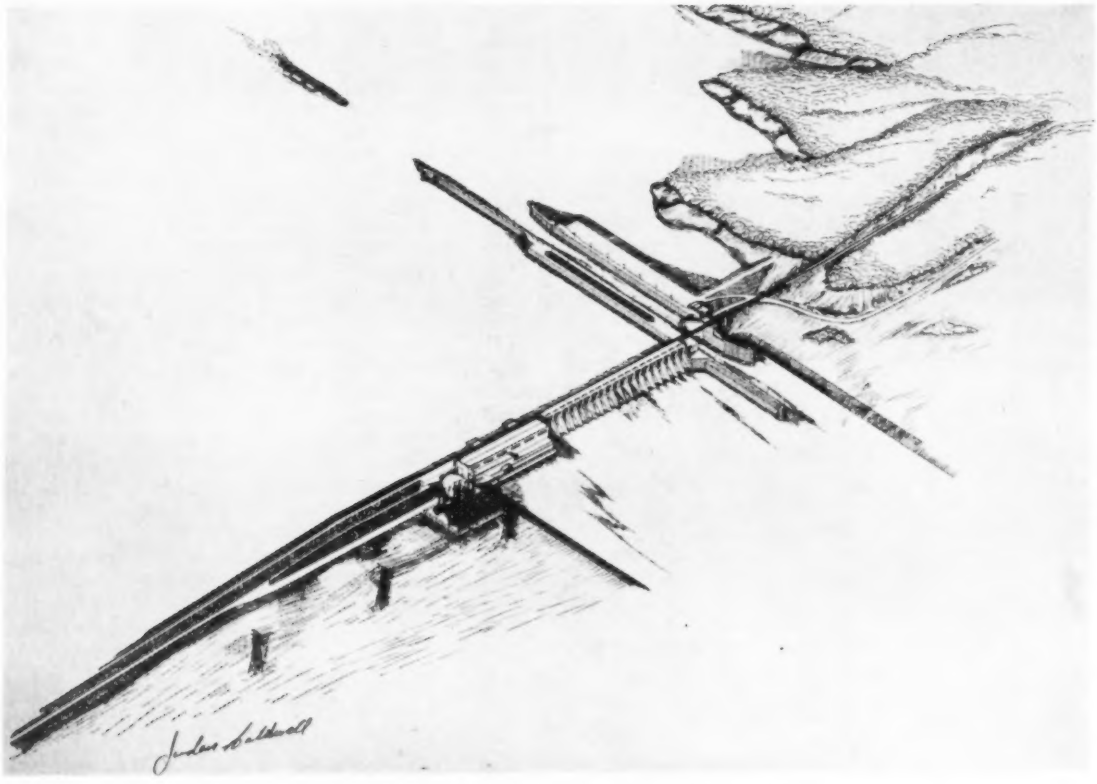


*Fig. 4. Artist's perspective of Barkley project*

between spray walls of 360 ft. It incorporates six tainter crest gates, 12 ft. by 60 ft., and is capable of discharging 166,000 cusecs into the bucket-type stilling basin. The four sluices in the spillway section have a total discharge capacity of 6,200 cusecs.

At this station the three penstocks are 15 ft. in diameter and deliver water at maximum, average and minimum operating heads of 154 ft., 140 ft., and 118 ft. respectively to the conventional type power house which contains three generating units, each of 18,000 kW capacity. The estimated minimum continuous prime power is 7,500 kW and the estimated total annual energy output is 127 million kWh.

Manufactured by the Westinghouse Electric Corporation, the 20,000 kVA rated generators have a guaranteed efficiency at full load, 90% power factor, of 97·15%; they incorporate Kingsbury-type thrust bearings and direct connected 150 kW, 250 V main exciters and 5 kW, 250 V pilot exciters. The Francis-type hydraulic turbines were made by S. Morgan Smith Co. and, at 140-ft. head, each has a rated capacity of 25,000 h.p., with a guaranteed efficiency of 90%, and a discharge, at full rating, of 1,750 cusecs. The turbines are spaced at 42 ft. centres, have a normal speed of 163·6 r.p.m. and are equipped with Woodward, actuator-type governors. There are three 18,000/24,000 kVA, three-phase, 13·2/69 kV transformers, while the circuit breakers are 69 kV, 600 amp., 1,000,000 kVA interrupting capacity type. Power is delivered at 69,000 V to the TVA.

Now partially in operation and due for completion in April 1958, the Old Hickory project is a combined power and navigation scheme and comprises a concrete gravity lock and dam structure and power house on the Cumberland River. The spillway is equipped with six tainter gates, 45 ft. by 41 ft., with individual electric hoists and sectional emergency bulkheads handled by power from the intake gantry. There is also a 17 ft. trashway with two-section vertical-lift gate, a power intake gate being used as an emergency gate.

The four power intakes, with three passageways each, have dimensions at gate opening of 17 ft. 8 in. width and 34 ft. 11 in. height and are equipped with continuous roller train-type gates with rubber seals. Hoisting is by 75-ton capacity gantry crane. Net operating heads are as follows: maximum possible, one unit running, 60 ft.; normal for design, 45 ft.; minimum for power, 18 ft.

In the power house are four 25,000 kW generating sets giving a total installed capacity of 100,000 kW and an estimated total annual energy output at plant of 420 million kWh. The General Electric generators are each rated at 31,250 kVA and have a guaranteed efficiency at full load, 80% power factor, of 96·5%. The thrust bearings are of the General Electric spring type, and the main exciters 300 kW, 250 V and the pilot exciters 17 kW, 250 V.

Kaplan turbines, manufactured by Baldwin-Lima-Hamilton Corporation are provided, each having a rated capacity at 45 ft. head of 35,000 h.p. They are spaced at 80 ft. centres and run at a normal speed of 75 r.p.m. The discharge of each turbine, with generator at full rating (45 ft. head), is 7,400 cusecs.

Governors are of the oil pressure, actuator type. The transformers are 43,200/57,600/72,000 kVA, three phase, 13·2/69 kV, while the circuit breakers are 69 kV, 1,200 A, 1,500,000 kVA rupturing capacity.

Of smaller dimensions and incorporating three 12,000 kW capacity generating sets, the Cheatham project on the Cumberland River has involved the construction of a non-navigable, gate-controlled spillway type dam with an adjoining lock for river traffic. The dam has an overall length of 495 ft. and a maximum height of 75 ft. The maximum operating head (one unit running) is 29 ft., and the minimum 9 ft. There are three intakes, each with three passageways. Wheeled gates with bronze bearings and rubber seals are used and the dimensions at gate opening are 18·66 ft. width and 35 ft. height. Hoisting is by 50-ton capacity gantry crane.

The power house, which will yield an estimated average annual energy output at plant of 160 million kWh, has been constructed in a 5-acre area at the side of the dam. It houses three Kaplan turbines, each with a rated capacity of 20,000 h.p. at 22 ft. head, manufactured by Newport News Shipbuilding and Dry Dock Co., and the three Westinghouse generators. The latter are each rated at 13,333 kVA and have a guaranteed efficiency at full load, 90% power factor, of 95·8 per cent. The main exciters are 170 kW, 250 V and the pilot exciters 12 kW, 250 V. There are three 12,000/16,000 kVA, three-phase, 13·2/69 kV transformers and the circuit breakers are of the 69 kV, 600 amp., 1,000,000 kVA interrupting capacity type. This project was begun in April 1950 and is due for completion in September 1958 when the No. 3 power unit is scheduled to go on the line.

The Barkley project is in the initial construction stage, and is also of the lock and dam type, and is intended for flood control, navigation and power. The lock and dam is a combined rolled-earth fill and concrete gravity structure, with a maximum height of approximately 130 ft. and a total length of 7,985 ft. The ogee-type spillway will have a net width between spray walls of 700 ft. and will be equipped with 20 fixed-roller, vertical-lift crest gates measuring 45 ft. by 35 ft. The stilling basin will be of the concrete apron type with an end sill.

Five turbo-generating sets, each of 26,000 kW capacity, will give a total annual average energy output of 600 million kWh. Net operating heads will be maximum 62 ft., normal for design, 44 ft., and minimum, 20 ft.

Upon completion of the entire Cumberland River power system, the average annual power benefits are estimated to be in excess of $25 million, and the projected average annual output of about 3,500 million kWh will be equal to 62% of the total residential, commercial and industrial demand of the four Tennessee metropolitan areas during 1954.

The development of the Cumberland River is under the jurisdiction of the U.S. Army Corps of Engineers, Nashville District.

# Book Reviews

**Water Power Development.** Vol. I. Low-Head Power Plants. By Dr. Ing. Emil Mosonyi. Published by the Hungarian Academy of Sciences (Akadémiai Kiadó, Budapest, V, Alkotmány u. 21, Hungary). 1957. 9¼ in. × 6¾ in. × 2 in. 908 pp. including index. 631 ff. Price £3 11s. 7d.

A review of the German edition of this excellent book was published in the January 1957 issue of WATER POWER and this, the English edition, leaves us little more to say than that the translation work appears to have been admirably done; although the English is not without a little awkwardness in places, it is always perfectly understandable. As we stated in our former review, this book is of peculiar interest to western technologists as it gives authentic particulars of Russian design work, especially in regard to power houses, intake structures, spiral casings, turbines and draft tubes. But it would be a mistake to suppose that the author has restricted himself in any way, and in fact he has neglected nothing to make his work as thorough and comprehensive as possible, having visited most western European countries and Brazil with this object in view. This comprehensiveness, combined with the author's mastery of detail, whether in theory or practice, makes Dr. Ing. Mosonyi's book the most notable of its kind yet published. Compared with the German edition, to which reference has been made, the English edition is considerably enlarged, as more diagrams and photographic illustrations have been added and entirely new technical reports and theoretical supplements have been included.

It should be understood that the present volume deals with low-head plants only and that Volume II, which is in course of preparation, will cover such matters as high-head stations, midget plants, pumped-storage systems and water-power economics generally.

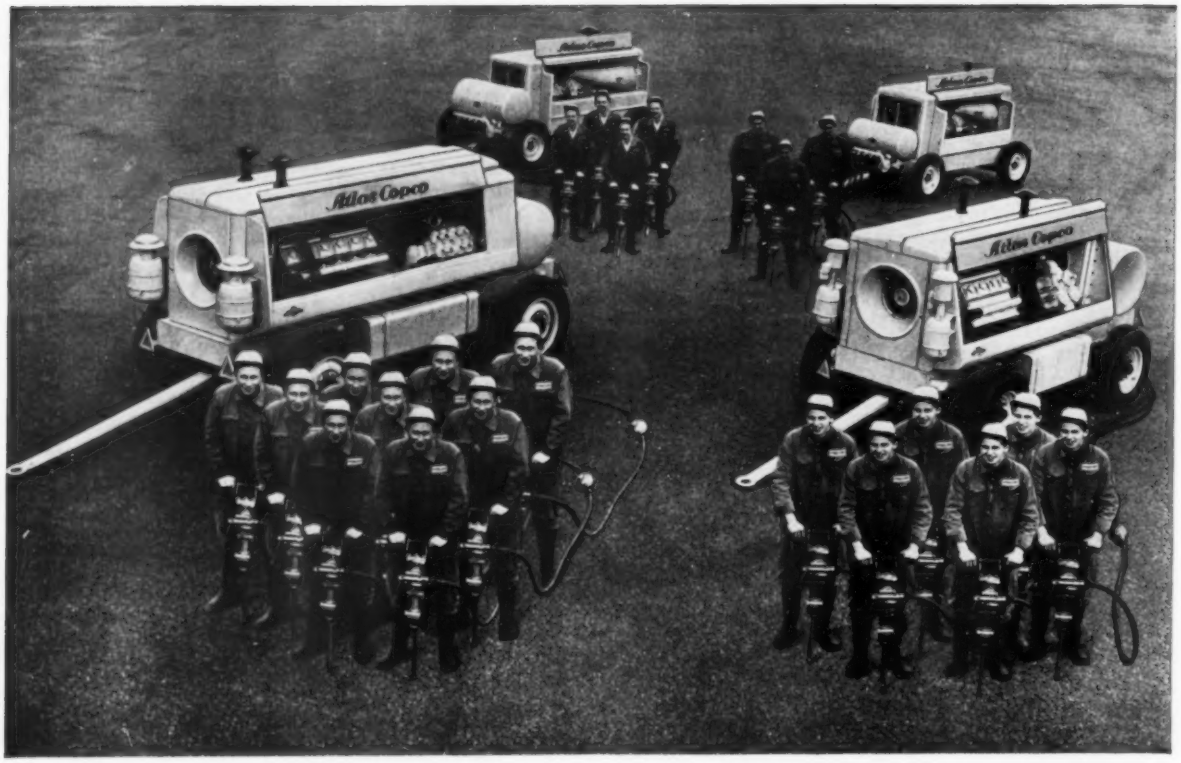
**British Standard Code of Practice for Site Investigations** (CP. 2001 : 1957). British Standards Institution, 2, Park Street, London, W.1. Price 20s.

This 124-page illustrated publication brings up to date Civil Engineering Code No. 1 (originally published in 1950 by the Institution of Civil Engineers). It deals mainly with the investigation of the suitability and characteristics of sites as they affect the design and construction of civil-engineering works and the security of neighbouring structures, but not with wider social and economic considerations affecting the community at large. The recommendations mainly apply to conditions existing in the British Isles, although occasional reference is made to conditions overseas where thought desirable.

The Code starts with a section dealing with the definitions, descriptions and classification of soils and rocks. The section includes a fold-out summary "Basis for field identification and classification of soils."

"General considerations governing site investigations" is very fully dealt with under the following heads: (a) Types of site investigation, (b) Site exploration, (c) Methods of sampling, and (d) Fields tests *in situ*.

The appendices convey by means of text, drawings




*Atlas Copco 500Dd, air-cooled, two-stage compressor, with Deutz, 12-cylinder air-cooled diesel engine. Sufficient to operate 9 rock-drills.*

*Atlas Copco 225Dd, air-cooled, two-stage compressor, with Deutz 6-cylinder air-cooled diesel engine. Sufficient to operate 4 rock-drills.*

*Atlas Copco 160Dd, air-cooled, two-stage compressor, with Deutz 4-cylinder air-cooled diesel engine. Sufficient to operate 3 rock-drills.*

*Atlas Copco 325Dd, air-cooled, two-stage compressor, with Deutz 8-cylinder air-cooled diesel engine. Sufficient to operate 6 rock-drills.*

# 4 new 100% air-cooled portables

## Capacities up to 600 cubic feet

Featured above are four of the new Atlas Copco range of completely air-cooled portable compressors—both compressor and diesel engine being 100% air-cooled. This new range is the most comprehensive of its kind in the world with capacities from 36 cu.ft./min. to 600 cu.ft./min., the latter being the highest capacity unit with complete air-cooling obtainable from any manufacturer.

### World-wide sales and service

Atlas Copco puts compressed air to work for the world. It is the largest group of companies specialising solely in the development and manufacture of compressed air equipment. It embraces Atlas Copco companies or agents manufacturing or selling and servicing Atlas Copco equipment in ninety countries throughout the world. For further details of the equipment featured here, contact your local Atlas Copco company or agent, or write to Atlas Copco AB, Stockholm 1, Sweden.

## Standard Features

**Complete air-cooling**—both compressor and engine air-cooled giving an equal, simple and economic design. Cuts out cooling system troubles, freezing damage, thermostats, radiator blind, anti-freeze solution, and boiling radiators in warm climates.

**Fuelmiser**—revolutionary stageless automatic speed control and automatic unloading device. Saves 15%-20% of fuel.

**Lubromatic clutch** governed by the oil pressure—safe and easy operation. If compressor runs out of oil the clutch disengages automatically.

**Automatic Drain Cock** on air receiver—one thing less for the operator to take care of.

**High efficiency oil-bath air intake filters.**

**Force-feed lubrication.**

**Automatic type steering,** low centre of gravity and wide track—makes transportation easy.

**Electric starting mechanism**—gives quick, easy start.

P7

**Atlas Copco**

*Manufacturers of Stationary and Portable Compressors, Rock-Drilling Equipment, Loaders, Pneumatic Tools and Paint-Spraying Equipment*

and tables a vast amount of information ranging from the highly technical to that having a useful reference value (such as the section on maps, charts and other data published by government departments). An important appendix is that which summarises information to be obtained concerning sites for civil-engineering works; and its complement "Special information required for design and construction." Another appendix contains a two-page table "Classification and characteristics of soils for roads and airfields." Again, a section on field tests is supplemented by very full information on the taking, handling, examination and testing of soil samples.

**Il Costo delle Grande Opere d'Ingegneria** ("The Cost of Large Engineering Works"). By Dott. Ing. Eugenio Campini. Published by Editore Ulrico Heopli, Milan. 1956. XXIV + 688 pp., 103 ff., 58 folding plates. Paper covers. Price 5,000 lira.

This excellent book fills an important gap in engineering literature. Nearly all textbooks are concerned ultimately with the problem of design, using the term in its broadest connotation to range from research, through theoretical analysis, to a review of current practice, but few, if any, have been published dealing with construction costs. This is surprising, as the engineer is concerned as much with cost as with design, although the lack is probably accounted for by the extent to which costs are regarded as confidential and are correspondingly difficult to elicit.

Dr. Campini's book is intended to repair this omission and it does so most effectively. Naturally, the figures he quotes relate primarily, although by no means entirely, to Italian practice, and mostly are those obtaining in 1954 or earlier, so that for engineers in other countries in 1958 the actual figures have only a relative value; but the real merit of the book lies in its painstaking and authoritative approach to the whole subject of cost analysis for large civil-engineering structures, so that the engineer capable of translating the information into terms of his own problems will find much to guide him. This process is rendered all the easier because the cost analyses are illustrated by the actual costs of a large number of important structures in Italy and in other parts of the world.

As we have already implied, the author deals with civil engineering over a wide range, but so much of his book is concerned specifically with hydro-electric practice that we do not hesitate to recommend it to our readers.

The book is divided into three parts, each of which contains numerous chapters. The first part is devoted to basic matters such as salaries, costs of materials, labour costs in relation to the execution of specific tasks such as transport, excavation, concreting, and so forth, and financing. Other chapters discuss the question of unit costs and give copious examples. A brief chapter in this section considers the special cost characteristics of hydro-electric concerns.

The second part deals with engineering works characterised by great physical length (e.g., river works, canals, sewers, etc.) or by their complexity. Under the latter heading there is an important chapter on hydro-electric schemes, which discusses the costs of free-flow and pressure tunnels and presents cost analyses of representative types of schemes.

But it is in the third part—dealing with physically localised undertakings such as harbours, docks, bridges, etc.—that most attention is paid specifically to hydro-electric undertakings, for here we have a series of chapters devoted to a full consideration of the construction costs of gravity, buttress, hollow, arched, rockfill, and earthfill dams, dam construction works, surge chambers, penstock anchor blocks, and surface-type and underground power houses.

Many other parts of the book are of interest to the hydraulic as distinct from the hydro-electric engineer. We have already mentioned river works, docks and harbours, and we must add that irrigation and water-supply engineers are well catered for. But the extent of the field covered has not been allowed to militate against the thoroughness with which each type of works has been handled, and we welcome a book that deals so admirably with a subject on which there is such a scarcity of published literature. Our readers should be reminded that the text is in Italian.

**Electrical Conductors—International Standard Sizes.** Obtained from British Insulated Callender's Cables Limited, 21 Bloomsbury Street, London, W.C.1. 84 pp. Price 15s. post free.

This standard reference book on electrical conductors has been compiled by the staff of British Insulated Callender's Cables Limited and the book contains, in tabular form, a comprehensive collection of all available data relating to electrical conductors, much of it hitherto unpublished. In its pages are detailed the nominal physical and electrical characteristics of the standard sizes of conductors in British, American and metric specifications over a full range of standard conductor materials: copper, cadmium, aluminium and steel-cored aluminium. For the latter material, British and American code words for sizes, where established, have been included.

The tables of conductor sizes are not confined to conductors for overhead lines, but include annealed copper and aluminium stranded conductors for insulated cables, and an extensive range of stranded-copper conductors as used in flexible cables.

The introduction to the tables is itself of great interest, containing as it does much rarely published information. Features of this are an explanation of the derivation of the tables and tables of stranding constants from which the area, resistance and weights of stranded conductors can readily be obtained. Further tables show clearly the constants and their reciprocals for resistance-temperature conversion between various temperatures and the standard of 20°C., and give conversion factors for standard units of length, area and resistance.

**Specification for Capacitors for Power Systems (Part III), Capacitors for Use Under Tropical Conditions** (I.E.C. Publication No. 70–3), International Electrotechnical Commission, 1 rue de Verembé, Geneva. Price 3 Swiss francs.

I.E.C. Publication 70–3 forms the third part of the Specification for Capacitors for Power Systems, the first part having been published in 1954 and the second part in 1955. Publication 70–3 contains only those amendments required to make Parts I and II applicable to capacitors for use under tropical conditions, and must consequently be used in conjunction with these Parts.

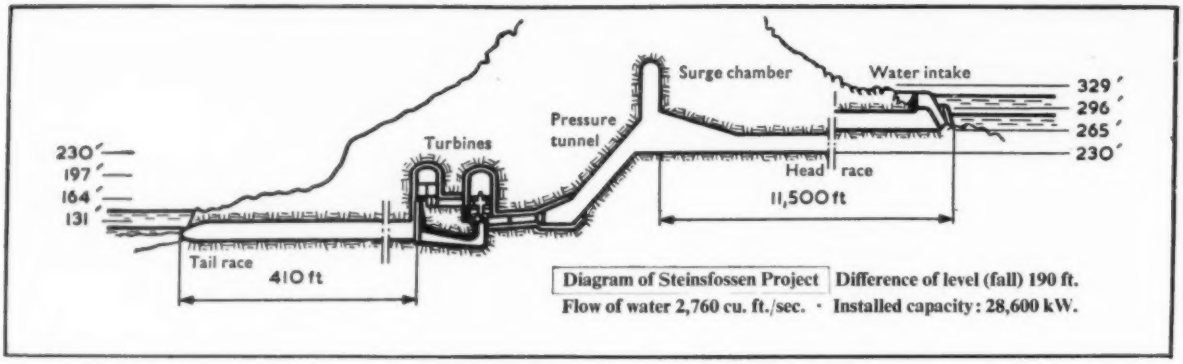



Diagram of Steinsfossen Project | Difference of level (fall) 190 ft.
Flow of water 2,760 cu. ft./sec. · Installed capacity: 28,600 kW.

# Atlas Copco equipment at Steinsfossen

## Shifts of only 8 men removed 2,300 cu. yds. per week in a 540 sq. ft. tunnel

AT THE HYDRO-ELECTRIC PLANT at Steinsfossen in Norway the contractors, A/S Høyer-Ellefsen, have chosen Atlas Copco compressed air equipment and Sandvik Coromant drill steels for all rock excavation. The head race tunnel at Steinsfossen, 11,500 ft. long and with a 540 sq. ft. section, has shown how swift, economical and simple tunnelling can be. Each week the tunnel was drifted 115 ft.—a particularly remarkable achievement for the number of men employed. This steady advance went on uninterrupted for week after week. Three shifts were worked daily *with only eight men doing all the tunnelling work*—drilling, blasting, mucking, and transportation. They were supported by two mechanics and one dump-clearer to a shift.

**World-famous drilling unit**

All drilling at Steinsfossen is done with Atlas Copco light rock drills and Sandvik Coromant integral steels. Specially developed over many years to work together, these drills and steels are now the most widely used drilling unit in the world. The ease and efficiency of this equipment is best illustrated by the fact that at Steinsfossen *eight men kept nine drills working simultaneously* at the face.

**Speedy Atlas Copco LM 200 Loaders**

At Steinfossen 240 cu. yds. of rock of big fragmentation were mucked-out per hour (effective loading time) by two LM 200 Atlas Copco Loaders. These loaders are particularly efficient because they are compact and narrow. Being railbound the minimum of space is required for manoeuvring and two can be used side by side at the face even in a relatively small tunnel. The loaders are also used for moving the drilling platform as the work proceeds. They are simple to operate and do not call for skilled workers.

**Dual purpose drilling platform**

Vital to the ease and speed of the whole operation was the Vinstra drilling platform which enables miners to drill from three levels. It has two movable beams on which the cars can be hung and swung across from one rail to the other. On the average car-switching took one minute.

**Facts about the Steinsfossen operation**

| | |
|---|---|
| Nature of rock: Granite | Head race tunnel: 11,500 ft. long 540 sq. ft. section |
| Approx. advance per year: 4,900 ft. | Average advance per week: 115 ft. (128 ft. max.) |
| Personnel per 24 hours: Foreman | 1 |
| Miners | 24 |
| Mechanics | 6 |
| Assistants | 2 (rail laying, ventilation, air and water pipes, etc.) |
| Dump-clearers | 3 |
| Total: | 36 |

*Drilling equipment:* 10 Atlas Copco rock drills type RH656 with pusher legs (one spare). Sandvik Coromant drill steels.

*Loaders:* 3 LM 200 (one spare). Loading time (including car-switching) 3.25 minutes per car of 4.4 cu. yds. capacity, i.e. 47 cu. yds. solid rock per hour and loader.

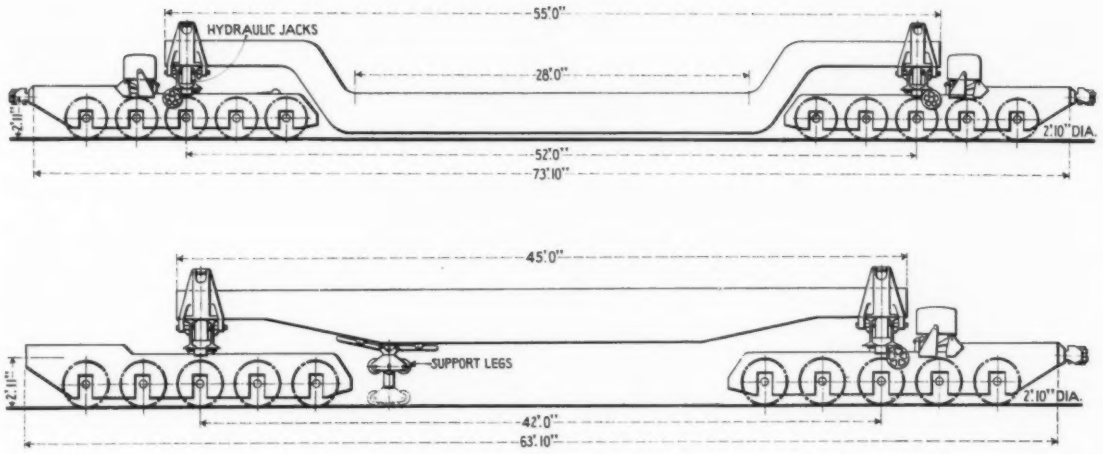
**World-wide Sales and Service**

The Atlas Copco Group embraces Atlas Copco companies or agents manufacturing or selling and servicing Atlas Copco equipment in ninety countries throughout the world. For further details of the equipment featured here, contact your local Atlas Copco Company or Agent or write to Atlas Copco AB, Stockholm 1, Sweden.

**Atlas Copco** *Manufacturers of Stationary and Portable Compressors, Rock-Drilling Equipment, Loaders, Pneumatic Tools and Paint-Spraying Equipment*

DSS 58

# Special-Duty Wagons for Kariba




*Arrangement of Head, Wrightson 102 ton wagons for Kariba, showing well-beam arrangement (above) and straight beams (below)*

Two special-duty 20-wheel, 3 ft. 6 in., gauge wagons are being built in connection with the moving of transformers and other heavy equipment for the Kariba hydro-electric scheme. The contract was awarded by the Federal Power Board for the supply of two 102 ton transformer wagons to Head Wrightson Teesdale Limited, a subsidiary of Head, Wrightson & Co. Ltd.

These vehicles will be used for transporting transformers constructed by Ferranti Limited and English Electric Co. Ltd. and other special loads, over some 1,000 miles of difficult country from the port of Beira over the Beira Railway to the Rhodesian frontier and thence over the Rhodesia Railways to railhead at Lions Den. The latter station is on the Sinoia branch, 140 miles by road from Kariba.

The well-type beams on these wagons are removable and can be replaced by straight high-side beams when special loads are to be carried. The underframe consists of two main side beams, each of which is built up by welding two mild-steel flange plates to a mild-steel web plate. The side beams at the centre are 35 in. deep; they consist of 12 in. × 2½ in. flanges and 1¼ in. thick web plates. The depth of the side beams beyond the well end above the bogies will be reduced together with the flange thicknesses. The load of 102 tons is equally transmitted through these side beams to end bolsters and so to the bogies. The side beams are held together by tubular crossbars, the end-plates of which will be bolted to the side frames.

Hydraulic jacks are provided in the bolsters, capable of raising the beams loaded by 1 ft., and removable joist crossbars are supplied between the well beams thereby giving support and to act as a floor in the well of the wagon when it is used for normal traffic.

The track that has been laid from Beira, where equipment for this project will be landed, crosses very difficult country, and for this reason, it is stated, the bogies on the wagons are of a special design. Two 10-wheel bogies will be provided with wheels at 3 ft. 7 in. centres, resulting in a fixed wheelbase of 14 ft. 4 in. The bogies are of welded construction, built up of mild-steel plates and rolled-steel sections, and provided with a compensating springing system. The maximum permissible axle load is 15 tons.

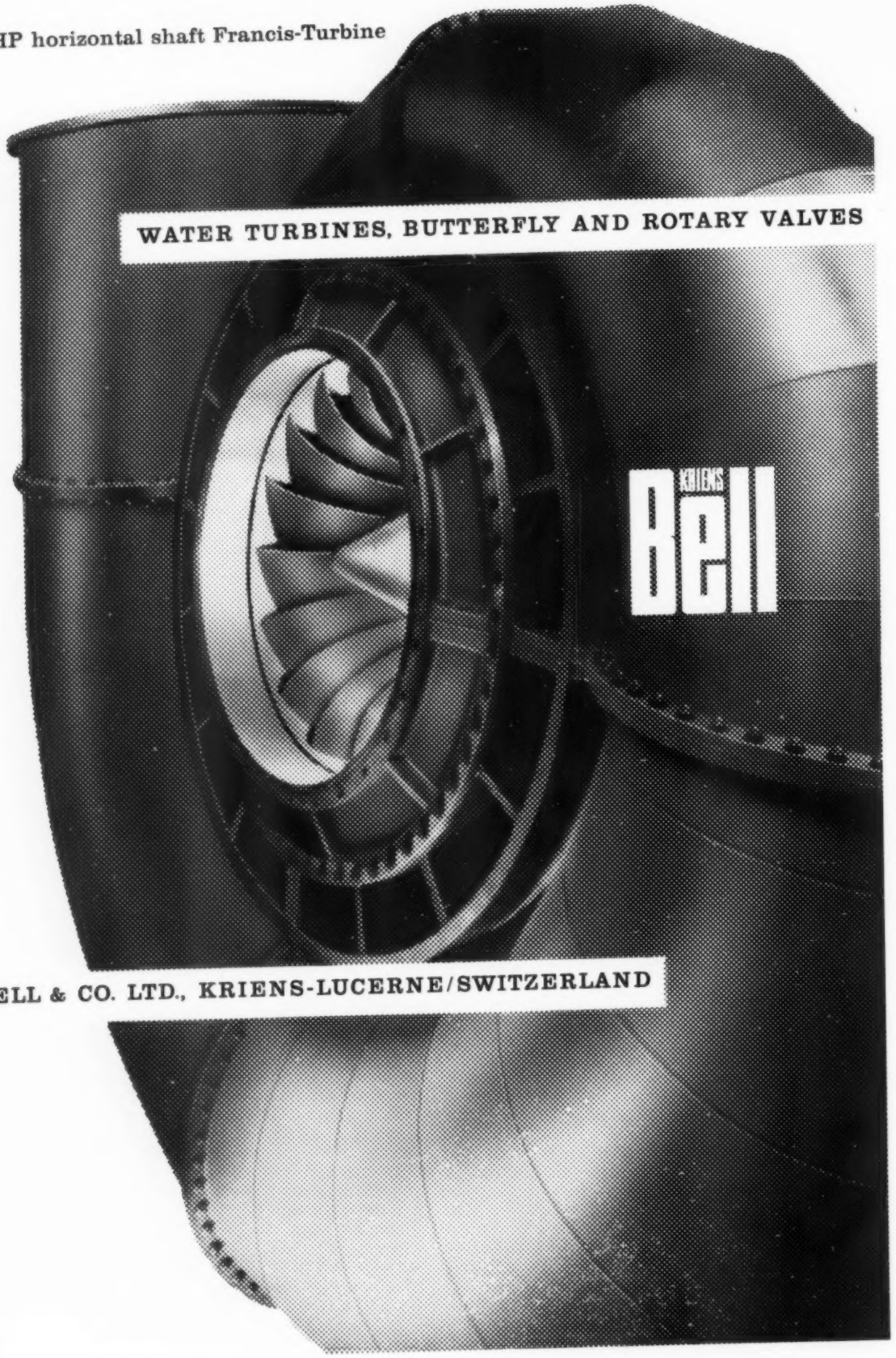
The inner axleboxes are supplied with sliding tops to allow for the transverse movement of the inner axles when the wagon is negotiating a curve. Axleboxes with plain bearings for 10 in. × 5½ in. diameter journals are located between horn guides attached to the bogie soleplates. The wheels are of the solid rolled-steel type of 2 ft. 10 in. diameter on tread.

The wagons are fitted with automatic couplers and draft gear arranged at a height of 2 ft. 11 in. from rail level to the centre line of coupler. The vehicles are equipped with automatic vacuum brakes, two cylinders for which are mounted on each bogie. They are arranged with a change-over mechanism, so that two 15 in. diameter cylinders may be used when the vehicle is light, and all four cylinders used when it is loaded.

---

**Flexible Ducting.** A well-indexed and comprehensive ready reference for engineers engaged in the planning or day-to-day operation of a ventilation system for tunnel driving has recently been published by Flexible Ducting Limited. The range of information given is extensive, the data dealing with such divergent problems as small-bore sewers and large-diameter hydro-electric tunnels many miles in length. Working charts and drawings illustrate air leakage and friction losses, and the seven chapters of the book cover fan systems, ventilation methods, pressures, and other relevant subjects. Test equipment and its uses and applications are also examined. This useful volume is available to authentic engineers on application to Flexible Ducting Limited, Shuna Street, Maryhill, Glasgow.

25 000 HP horizontal shaft Francis-Turbine



# Abstracts from the World Technical Press

## Effect of Boundary Resistance on Solitary Waves

This paper reports on the results of an investigation into the attenuation of solitary wave amplitude conducted in the Hydrodynamics Laboratory of the Massachusetts Institute of Technology. The tests were carried out in a lucite channel 32 ft. long and 16½ in. wide, with water depths ranging from 0·2 to 0·4 ft. Some runs were made with the tank bottom artificially roughened with gravel of uniform diameter. Attenuation results are compared with available theory. In another phase of the study, it was attempted to approach the damping problem by direct measurement of the transient boundary layer near the bottom. A special differential gauge for measuring the low transient velocities was designed and the preliminary results obtained with it are described. (Arthur T. Ippen, Professor of Hydraulics, Massachusetts Institute of Technology, and Gershon Kulin, Hydraulic Engineer, National Bureau of Standards, Washington, D.C., *La Houille Blanche*, Vol. XII, No. 3, July–August 1957, p. 401, 7 pp., 8 ff.)

Note: The illustrations appear in the French translation of this paper, at the end of which the references are also printed (pp. 390 to 400).

## Prefabricated Asphaltic Blankets

This article describes, together with a few of its practical applications, the process initiated a few years ago in U.S.A. for ensuring the watertightness of reservoirs, canals and other hydraulic structures, by means of prefabricated asphaltic blankets. These can be easily transported in bundles of 50 to 60 pieces and assembled by hand on site into perfectly impervious linings without the help of any special material. Workers accustom themselves very soon to the new technique and daily outputs of 300 to 400 square metres can easily be attained by teams of 10 men. The blankets, once fitted into the correct position, are welded together by means of an adhesive which is spread while hot. Thanks to their flexibility, assemblies of these blankets cling easily to the ground and follow eventual deformations of the surface without breaking. This technique has now been adopted in France, and has been successfully applied to irrigation canals. (*Travaux*, Vol. 41, No. 274, August 1957, pp. 441/442, 7 ff.)

## Fish Guide and Trapping Device

This short note describes the fish guiding and trapping device installed by the Washington State Department of Fisheries to test its effectiveness for capturing downstream migrants at dams where the water level is drawn down periodically. The trap, placed in the forebay of the Mud Mountain flood control dam on the White river south-east of Seattle, sets up a current to attract young salmon migrants; it is 36 ft. long, 12 ft. wide, 6 ft. deep and weighs 10,000 lb. A 42 in. pump with a capacity of 30,000 gallons per minute moves water into the trap; the water passes through louvers set on an angle to repel the fish and guide them into a 6 in. channel leading to a live box. A 5 in. pump of 600 gallons per minute capacity attracts the fish into the live box from the trap. Under the test schedule at Mud Mountain dam, the fish trapped will be transported around the dam in a tank truck but in a permanent installation fish would be passed by means of a chute or pipe. (John M. Hingst, *Engineering News-Record*, Vol. 159, No. 14, October 10, 1957, p. 52, 1 f.)

## Noxons Rapids Dam

This project of the Washington Power Company, which is causing big problems of relocation upstream, consists of three principal sections. The first of these consists of a central concrete section with a spillway block on the right bank of the Clark Fork river and an intake and power-house block on the left bank. This is flanked by two earthfill sections, 1,800 ft. long on the north and 3,000 ft. long on the south, involving an aggregate fill of 4 million cu. yards. Outstanding features of the project are the cost of adjusting existing highways, railways and transmission lines near the reservoir area, which will be about the same as the actual construction cost of the dam and power house; the use of high yield strength, low-carbon T-1 steel for the turbine scroll cases; and the plugging of a deep gorge in the rock foundation for the north embankment with a grout curtain topped by a sheet-pile cutoff wall. The central concrete block, 1,130 ft. in total length, will back up water for 38 miles in a reservoir of 380,000 acre-ft. capacity. Of this amount, 80,000 acre-ft. will be usable controlled storage with a 10 ft. normal drawdown, but with additional drawdown if required. The dam crest is at El. 2340 with a maximum high-water level at El. 2331, the normal gross operating head being 154 ft. The power house is being built for five 100,000 kW units which will be driven by 137,000 h.p. Francis turbines ranking among the largest of their kind. The initial installation is four units. Since the present power demand is not nearly as acute as in the case of Cabinet Gorge dam, whose construction was compressed into 1½ years, the Noxon Rapids schedule covers a four-year construction period and will not generate power until the autumn of 1959. River diversion is ensured by a two-stage cofferdam system which involves excavation of 75,000 cu. yards of fill for the upstream unit and 60,000 cu. yards for the downstream unit. The embankments were made by dumping large rock from a bridge and filling in behind with smaller material. As such cofferdams are by no means watertight, the construction is protected by a substantial pumping installation that will total 160,000 g.p.m. when in full operation. Concreting and other construction operations are being handled from a 938 ft. long construction trestle that has a maximum height of 105 ft. The automatic concrete batch plant is located about 500 ft. from the trestle. As the riverbed aggregate deposits and the aggregate plant site itself will be inundated, a storage capacity for 80,000 cu. yards of concrete has been provided. Concreting will proceed up to December when there will be a two or three-month shutdown during the worst winter weather. The two wing dams are substantially different in nature, the north embankment being curved to follow a rock ridge, and the south embankment relatively straight. The con-

CP136

CONSOLIDATED PNEUMATIC MAKE OVER 480 DIFFERENT MODELS OF POWER TOOLS

# This is the C.P.117 CONCRETE BREAKER

*ONE OF A WIDE RANGE OF CONTRACTORS TOOLS*

Long experience has built into C.P. Concrete Breakers that perfect combination of durability, power and balance which is so essential in demolition tools.

The rugged C.P.117 illustrated above, with its slower, heavier blow gives continuous service under the most extreme conditions — trenching, pile driving, the tearing out of concrete and brick foundations and walls, but light and medium patterns are available which cover every contracting need.

Write for Publication S.P. 365.

## Consolidated Pneumatic

CONSOLIDATED PNEUMATIC TOOL CO. LTD., 232 DAWES ROAD, LONDON, S.W.6

AIR COMPRESSORS · PNEUMATIC TOOLS · ELECTRIC TOOLS · CONTRACTORS EQUIPMENT · ROCK DRILLS · PUMPS · DIAMOND DRILLS

creting procedure and the construction of the earthfill wings is described in detail. Appended to the article are a short note on the T-1 steel used for the turbine scroll cases and an account of the massive relocation work which actually constitutes a major part of construction work. (*Engineering News-Record*, December 5, 1957, p. 60, 9 pp., 16 ff.)

## Discharge Coefficient of Weirs

A detailed account is given of the extensive model tests carried out at the Central Water and Power Research Station, Poona, in connection with the proposed Hanumannagar dam on the Kosi river. The object of the experiments, carried out with various upstream and downstream slopes of the weir profiles, was to facilitate the choice of the most efficient solution, that is to say, a weir profile which would allow the maximum discharge to pass over with the minimum of afflux. As such the discharge coefficients of the various profiles for free-flow conditions only were determined. The test model set up was a parallel-sided flume on a scale of $^1/_{40}$ and the experimental procedure is described in detail, the results obtained being given in two tables and two graphs. Similar experiments carried out at the Poona Research Station in connection with the Lloyd Barrage at Sukkur, as well as by the Punjab Irrigation Research Institute, the Poondi Irrigation Research Station, and the U.S.A. Bureau of Reclamation (Boulder Dam), are reviewed in an appendix. (S. V. Chitale, *Irrigation and Power*, Vol. 14, No. 2, April 1957, p. 184, 28 pp., 23 ff.)

## Hydro-electricity in the Libyan Desert

This paper reviews and discusses the possibility of harnessing the Qattara Depression to hydro-electric production. The Egyptian tract of the Libyan desert between the meridians of Sidi Barrani in the west and El Alamein in the east, rises gradually southwards from the coast to the interior, to reach, at a distance of 60 to 70 km. from the sea, a height varying between 150 and 200 m. above sea level. It then drops abruptly to form a vast hollow measuring 250 km. by 150 km. This is the El Qattara Depression, about 20,000 sq. km. in area with an average depth of 60 m. below sea level, and 134 m. at its lowest points. The idea of creating an artificial lake appears to go back to the first discovery of the depression, and was first suggested by John Ball, director of the Egyptian Survey, and subsequently shelved because of its cost. The author examines the problem in all its aspects. The geological composition of the depression is favourable; precipitation, at present no more than 20 mm. a year, may reach twice as much, once the hollow has been transformed into an artificial lake. Evaporation is, of course, an important factor; assumed at 2 m. a year for a sweet water lake, it would be less at El Qattara, since the water diverted from the Mediterranean would have a high degree of salinity. As to ground flow, assuming a lake 13,500 sq. km. in area, incoming seepage is estimated at no more than 75 mm., while outgoing seepage is practically negligible. Taking all the above factors into account the author calculates that the discharge necessary to maintain the water level of the artificial lake at 50 m. below sea level would ultimately be 630 cu. m. per second, following two preliminary stages of 210 and 420 cu. m. per second for the first and second period of 25 years respectively. Assuming a generating efficiency of 85% power production is assessed at 65 MW, most of it to be transmitted at a loss of about 10% to the consumption centres in the Delta. The paper then examines briefly the layout of the water conduits which would consist of a gravity canal connecting with a tunnel at a distance of about 20 km. from the sea, and concludes with a short study of the salinity of the lake brought about by the water drawn from the sea and of the possibility of setting up a salt extracting plant. (Professor Ing. Dino Zanobetti, Communication read to the Bologna Section of the Asociazione Elettrotecnica Italiana, June 15, 1957, 12 pp., 8 ff.)

## Canadian Yukon River Development

This paper was read at the 71st Annual General and Professional Meeting of the Engineering Institute of Canada, Banff, Alberta. A brief historical survey is given of the many studies which have been made of the possibilities of developing power from the water resources of the Yukon area, and the political and physical problems are discussed. The political problems arise out of the fact that the Yukon River is an international stream with its source in Canada and its mouth in Alaska. Its total length is 1,700 miles, of which about 570 miles are in Canada. Some surveying work was done in co-operation with U.S.A. in 1950 until, towards the end of the year, the Government of Canada decided that it was not in the national interest to divert Canadian water to another country for power if it could be developed and used in Canada. In 1952-53, the large mining organisation, Ventures Limited, coupled with its subsidiaries, Frobisher Limited and Quebec Metallurgical Industries Ltd., became interested in the project and asked the author to act as consulting engineer and see whether four or five million horsepower could be developed at a competitive cost. A condition laid down by the Government of Canada was that any such power project would have to be planned so that generating plants and industrial plants included in the project would be in Canada. In 1954, the companies interested incorporated a subsidiary, Northwest Power Industries Limited for the purpose of making power investigations, and planning constructing and operating power projects. From the two courses open at this stage, the first, which involved the setting up of a series of large dams on the Yukon River, was discarded as not economically feasible in favour of an alternative which complied with the Dominion Government's requirements by reversing the northerly flow of the upper waters and taking these south through the lower end of Atlin Lake to low valleys in British Columbia, so affording operating heads ranging from 500 to over 1,000 ft. Field surveys and engineering investigations have been under way in accordance with this general plan since 1953. All the special factors associated with the Yukon Project, such as climate, seismic disturbances, fisheries, other power potentials and the effect of glacial areas, are dealt with in this paper. The power plan proper is divided into four stages which are briefly described. While information for the design of stage 1 and certain features of stage 2 is now available, much definitive information is still required for stages 3 and 4. Actually the latter two stages are many years in the future, and the time of their construction will depend upon the development of the large power market that will be necessary. Stage 1 centres round a power sta-

tion on the Nakonake river which would operate under a gross head of 1,090 ft., and have an estimated capacity of 880,000 h.p. Stage 2 aims at adding the water from Teslin lake and Teslin river to the storage involved at stage 1, thus increasing the capacity of the Nakonake river station to 1,540,000 h.p. Eventually stage 3 would raise the capacity of the system to 2,800,000 h.p. As to stage 4, a promising dam site was located during 1956 on the main stem of the Taku river just below the mouth of the Inklin river; a subsequent survey established that part of the natural flow of both rivers could be impounded at that spot and give, with the northerly waters, a discharge of well over 30,000 cusecs. Here an additional 600,000 h.p. would increase the aggregate potential to 4,900,000 h.p. The paper concludes with a review of possible industrial sites and power markets in the Canadian Northwest. (*The Engineering Journal*, Canada, Vol. 40, No. 11, November 1957, p. 1,638, 10 pp., 10 ff.). J. M. Wardle, M.E.I.C.

## Ova Spin Project

This power project is situated on the Swiss stretch of the Inn, a tributary of the Danube, and is to a certain extent an international venture as it is being constructed as a result of an agreement arrived at on May 27 of last year between Italy and Switzerland. By this agreement the Italian authorities grant the Swiss the use of the 180 million cu. m. Lavigno reservoir as well as the right to build and operate the Livigno power station just as though they were purely Swiss enterprises. The project worked out by the Engadiner Kraftwerke A.-G. (EWK), comprises the following main sections: (a) The Chamuera Reservoir (55 million cu. m.) which will be created by a 120 m. high arch dam and will operate the S-Chanf power house through a 7,600 m. tunnel and a 1,050 m. pressure shaft separated by a surge tank. (b) The upper Inn stage, S-Chanf-Pradella, will utilise the waters of the upper Swiss stretch of the river, of the Spöl and a few other tributaries; a canal will convey the discharge of the S-Chanf plant to a balancing reservoir at Ova Spin from which a pressure tunnel 21·6 km. long will lead to the surge tank above the Pradella power house. (c) The Pradella-Martina section, on the Lower Inn, will include a balancing reservoir of 500,000 cu. m. in capacity which will also collect the discharge from Pradella and feed the underground Martina plant through a pressure tunnel, 14·1 km. long, and two pressure shafts, with a surge tank in between. (d) The run-of-river plant at Tasna will utilise the waters from five left-bank tributaries of the Inn between the villages of Susch and Ardez through a system of gravity and pressure tunnels 17·8 km. in aggregate length. (e) The Livigno Reservoir will feed the underground Ova Spin power house by means of a pressure tunnel, 7 km. long, leading to a surge tank from which a pressure shaft leads to the machine hall. (f) The Italian Alto Spöl diversion, acting as a compensation for the grant of the use of the Livigno Reservoir to Switzerland, will return to the plants of the Italian Adda system an average yearly volume of 97 million cu. m. of water. The whole system will drain a total area of about 3,260 sq. km., not including an area of 104·8 sq. km. drained by the Alto Spöl diversion. The total installed capacity will exceed 400 MW, in addition to the 28 MW pumping plant at Ova Spin. The aggregate production is estimated at 682 million kWh in winter and 786 million kWh in summer. On the basis of the prices in force in the autmun of 1956, total expenditure for the construction of the Ova Spin system is assessed at Sw. Fr. 722 millions (about £59 m.). (M. Philippin, *Bulletin de l'Association Suisse des Electriciens*, Vol. 48, No. 22, October 26, 1957, p. 973, 8 pp., 3 ff.)

## The Caland Project

Although no hydro-power development appears to be envisaged in this great iron-ore mining venture, the water-control projects involved entail the construction of no less than twenty dams, most of them earthfill, and a few rockfill or concrete structures together with associated controls. The first instalment of this paper deals mainly with the water control projects. (Philip D. Pearson, *The Engineering Journal*, Canada, Vol. 40, No. 11, November 1957, p. 1,657, 8 pp., 18 ff.)

## Bhakra Dam Studies

Model investigations established that in the Bhakra right-bank diversion tunnel, as originally designed, negative pressures occurred in the conduits and the gate grooves, and that the tunnel did not run full under any circumstances. It was consequently decided to alter the design, and a new range of tests was carried out on a model incorporating the modified features. These features included an additional arch at the top of the conduit above the full supply level in the tunnel, a gate housing larger than the gate and a small inlet upstream of the gate, so as to ensure the aeration of the issuing jet from all sides. A detailed analysis of the tests, which proved fully satisfactory, is given in a paper presented to the 26th Annual Research Committee Meeting of the Punjab Irrigation and Power Research Institute held in Amritsar in July 1956. (*Irrigation and Power*, Vol. 14, No. 12, April 1957, p. 245, 17 pp., 15 ff.)


**CLASSIFIED ADVERTISEMENTS**

*Announcements for this column can be accepted up to the 8th of the month for the following month's issue. The charges are fourpence per word with a minimum of 10s. Box No. facilities 2s. 6d. extra. In order to avoid accountancy it would be appreciated if instructions to insert were accompanied with remittance.*

*Displayed classified advertising for situations vacant, situations wanted, public appointments, are accepted at £2 10s. 0d. per column inch.*

**CAPITAL**

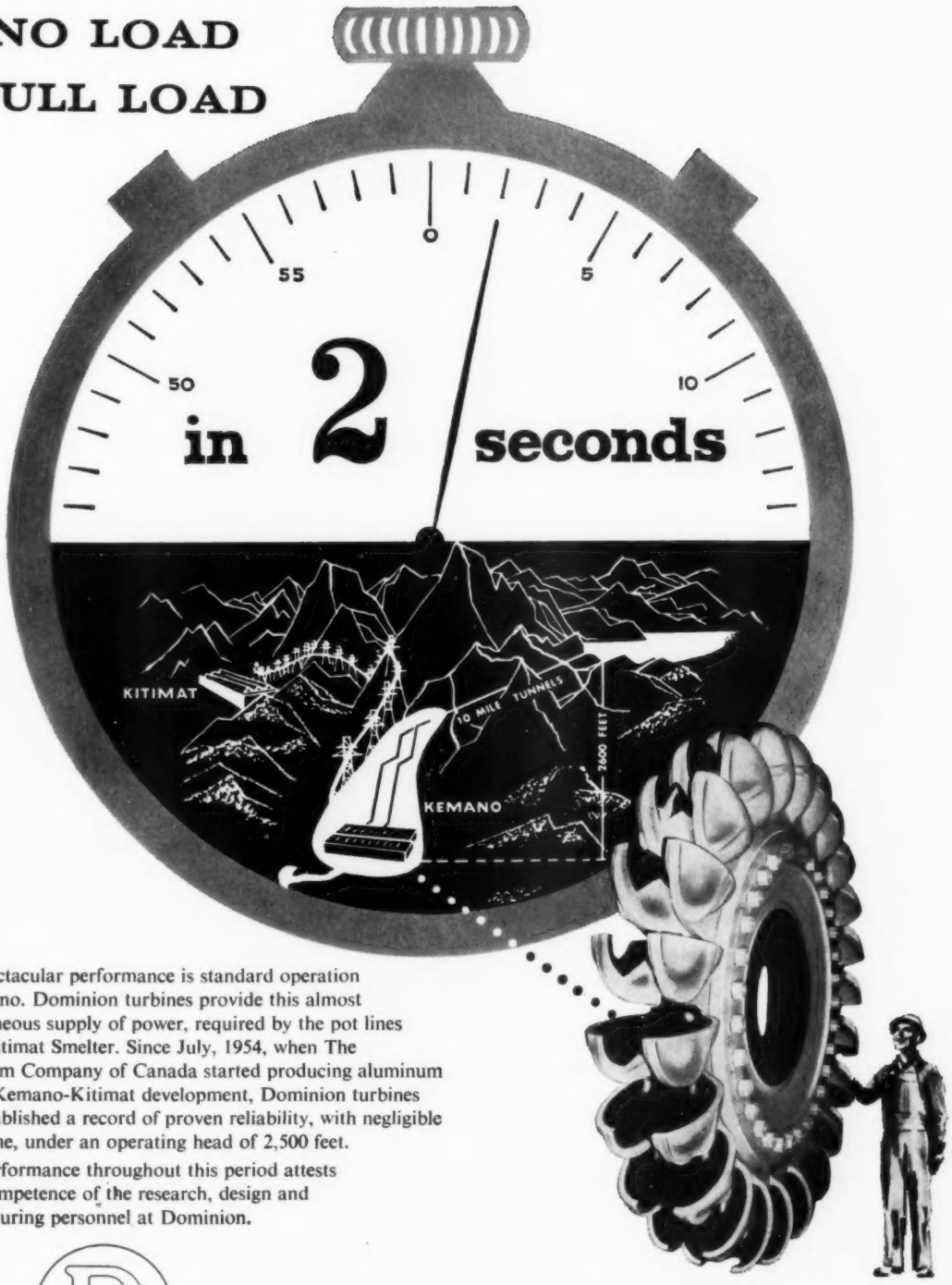
Financing Hydro Electric, Atomic, Diesel or Transmission Lines, East or West. Public, private, new projects, expansion, for betterment of your community. Retired utility owner, industrial builder, experienced organisation financing. Write air mail type plant desired, population. *Peter J. Minck, 1461, Ashland Avenue, Columbus 12, Ohio, U.S.A. Phone Ax 9–1126.*

**Appointment Vacant**

HYDRO-ELECTRIC ENGINEER required by Consulting Engineers for planning, design and layout of hydro power stations at home and abroad and in particular handling of water turbine contracts. General knowledge of electrical power station plant or civil engineering work is desirable, and experience of water turbine design and manufacture would be an advantage though not essential. Applications with full details of experience and salary required, quoting reference WWC, to Merz and McLellan, Carliol House, Newcastle-upon-Tyne.

## DOMINION 150,000 H.P. IMPULSE TURBINES ON THE LINE AT KEMANO . . .

from **NO LOAD**
to **FULL LOAD**




This spectacular performance is standard operation at Kemano. Dominion turbines provide this almost instantaneous supply of power, required by the pot lines at the Kitimat Smelter. Since July, 1954, when The Aluminum Company of Canada started producing aluminum at their Kemano-Kitimat development, Dominion turbines have established a record of proven reliability, with negligible down time, under an operating head of 2,500 feet.

Their performance throughout this period attests to the competence of the research, design and manufacturing personnel at Dominion.

**DOMINION ENGINEERING**
COMPANY LIMITED
MONTREAL • TORONTO • WINNIPEG • VANCOUVER

# CHARMILLES

## CHARMILLES ENGINEERING WORKS LTD. - GENEVA

**31 000 HP**
**RUNNER FOR THE HIGHEST HEAD**
***in the world***
**5,800 FEET**

***The highest head***
**in AMERICA**
**3,700 FEET**
**is also equipped with**
**CHARMILLES TURBINES**
**LOS MOLLES POWER PLANT**
**Two 12,650 HP units**

EXCERPT
FROM CHARMILLES
REFERENCE LIST

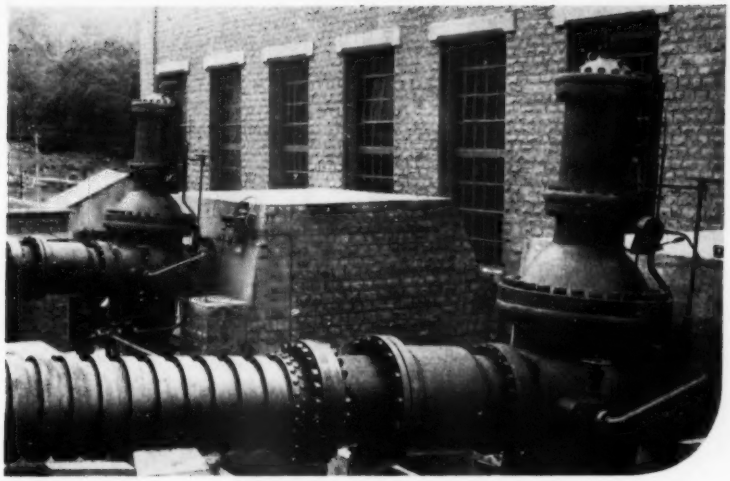
### THE SIXTEEN HIGHEST HEAD TURBINES IN THE WORLD

| Installation | Number of units | Net head feet | Unit output HP |
|---|---|---|---|
| Reisseck (Austria) ... ... ... ... | 3 | 5,800 | 31,000 |
| Dixence (Switzerland) ... ... ... | 5 | 5,700 | 50,000 |
| *Fully (Switzerland) ... ... ... ... | 4 | 5,400 | 3,000 |
| Miéville (Switzerland) ... ... ... | 3 | 4,730 | 47,500 |
| Portillon (France) ... ... ... ... | 1 | 4,280 | 53,500 |

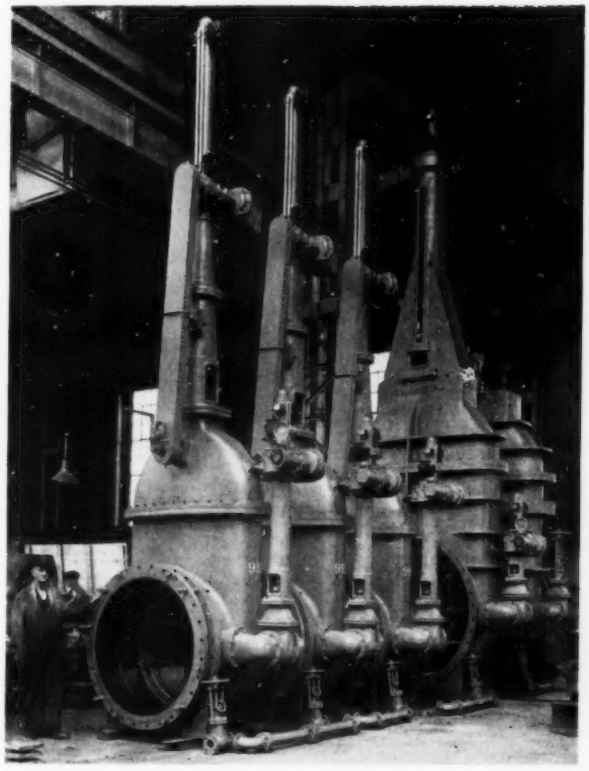
*manufactured in the time of Pic-Pic

**No other turbine in the world operates with a head equal to or higher than any of the above**

*At the Power House*



# SLUICE VALVES



**Countless Glenfield Sluice Valves, in wide ranges of type and size for an equally wide range of pressures, have been supplied for turbine isolation and other purposes at the power houses of hydro-electric plants in many countries.**

**The styles cover round-bodied parallel-faced valves for high head conditions, oval-bodied units with wedge-shaped doors for medium and low pressures, and follower-ring valves for situations where frictional head losses through a valve have to be at a minimum.**

**Illustrated at site—Pykara Power House, India—are 26 in. dia. hydraulically operated follower-ring valves for 3,080 ft. head; and in our works 51 and 75 in. dia. electrically-operated oval-bodied wedge gate units.**

*Head Office and Works:* KILMARNOCK, SCOTLAND

Glenfield

GLENFIELD & KENNEDY, LIMITED, KILMARNOCK

BPC

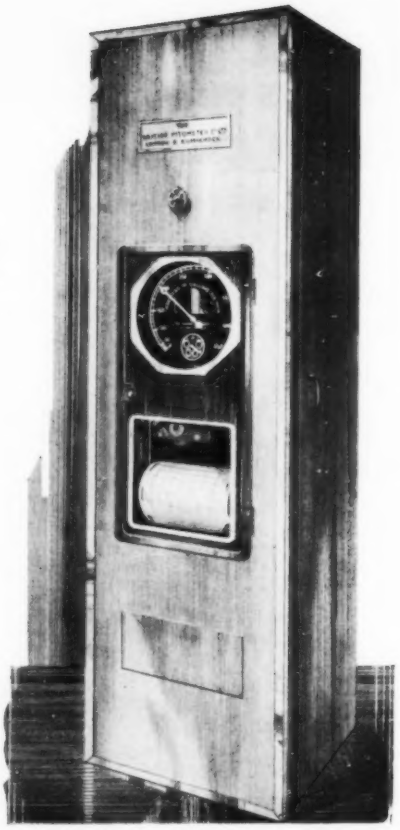
# Measuring Equipment
## FOR HYDRO-ELECTRIC PLANTS

**WATER FLOW**
in Tunnels, Pipe Lines and at Turbines.

**WATER LEVEL**
at Dams and in Surge Shafts for all depths and conditions.

**PRESSURE RECORDERS, *ETC.***
backed by over 20 years' experience in this specialised field. can be supplied for local or remote operation.

*The illustration shows the type of Flow Meters made for the North of Scotland Hydro-electric Board.*



## The British Pitometer Co. Ltd.
(ASSOCIATED WITH GLENFIELD & KENNEDY LTD.)
52 MINERVA ROAD, PARK ROYAL, LONDON, N.W.10

# ★ANDERSON—*Leading Manufacturers of Derrick Cranes*

5-ton Electric Derrick Crane x 130 ft. Jib

Some Exclusive Features:

- **Unit Gearing, construction of most progressive design.**
- **Visibility—unobstructed and clear view all the time.**
- **High speed operation with safety.**
- **Rugged construction of both machinery and structure.**
- **Interchangeable spares available promptly.**
- **Economical in operation.**

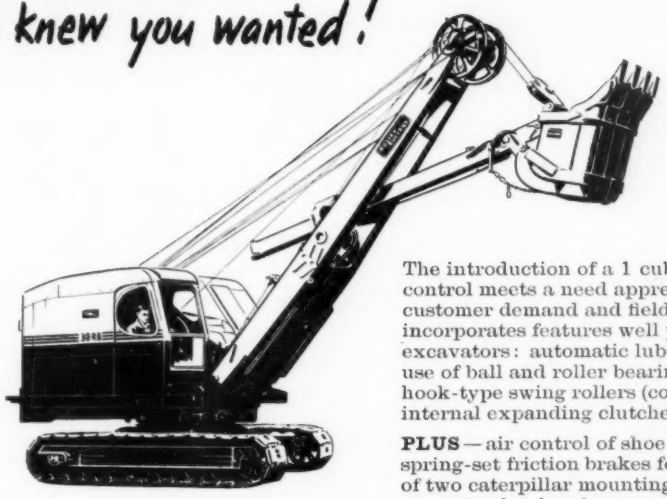
Phone:
CARNOUSTIE
2214-5

ANDERSON

THE ANDERSON-GRICE CO. LTD.
TAYMOUTH ENGINEERING WORKS, CARNOUSTIE, SCOTLAND

Grams:
"DIAMOND"
CARNOUSTIE

# The excavator we knew you wanted!



The introduction of a 1 cubic yard excavator with air control meets a need appreciated from analysis of customer demand and field experience. The 30-RB incorporates features well proven on the smaller R-B excavators: automatic lubrication and total gear enclosure; use of ball and roller bearings throughout main machinery; hook-type swing rollers (compensated type at front); internal expanding clutches with interchangeable parts.

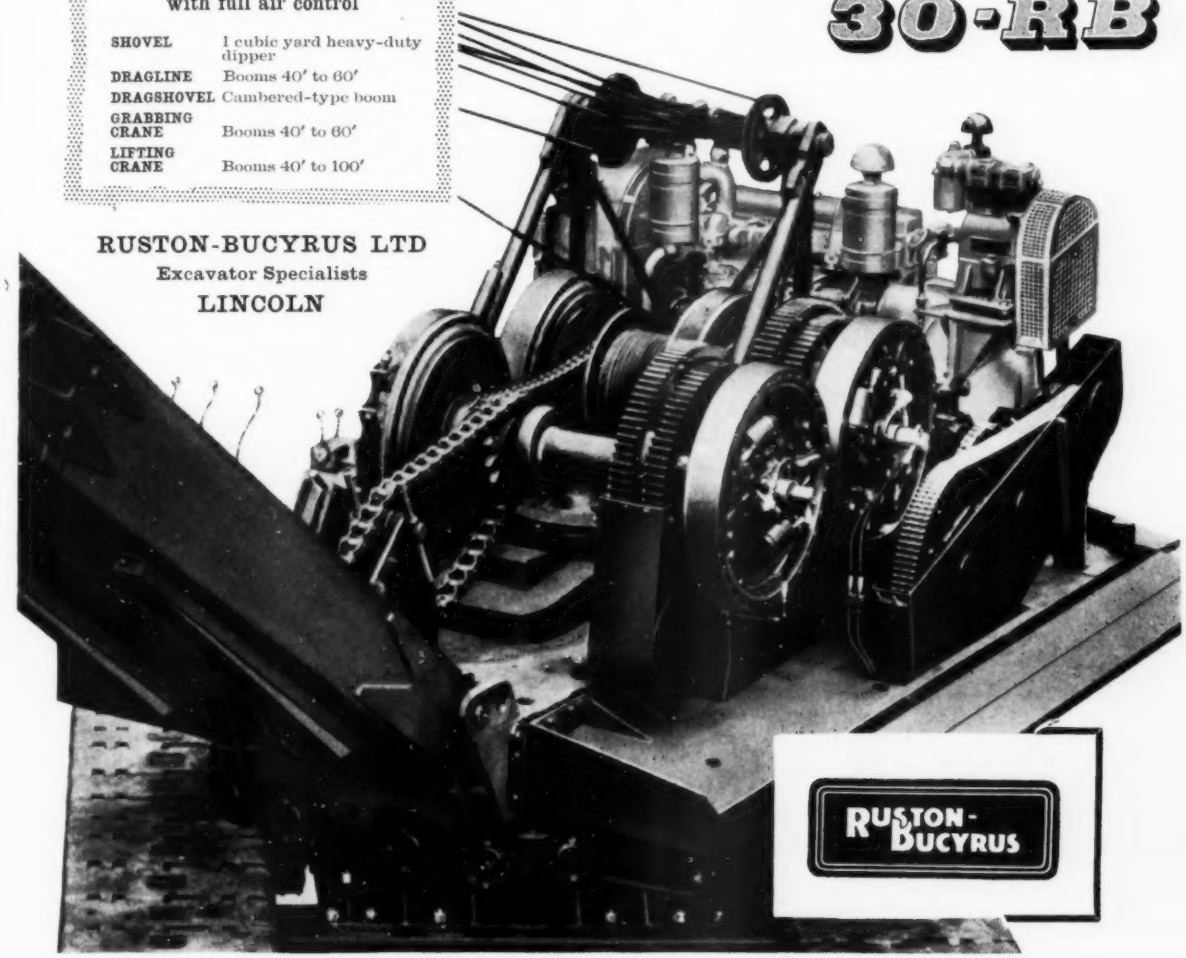
**PLUS**—air control of shoe-type clutch bands; air released, spring-set friction brakes for steering and digging lock; choice of two caterpillar mountings; individual boom hoist with separate clutches for power up or down; lubrication for swing rack and pinion with remote manual control; friction-type swing brake and superstructure lock; roller chain primary transmission, Ruston 5 YFN engine, and power-controlled load lowering (crane).

A specification on the 30-RB is available on request.

**The 30-RB**
**universal excavator**
**with full air control**

| | |
|---|---|
| **SHOVEL** | 1 cubic yard heavy-duty dipper |
| **DRAGLINE** | Booms 40′ to 60′ |
| **DRAGSHOVEL** | Cambered-type boom |
| **GRABBING CRANE** | Booms 40′ to 60′ |
| **LIFTING CRANE** | Booms 40′ to 100′ |

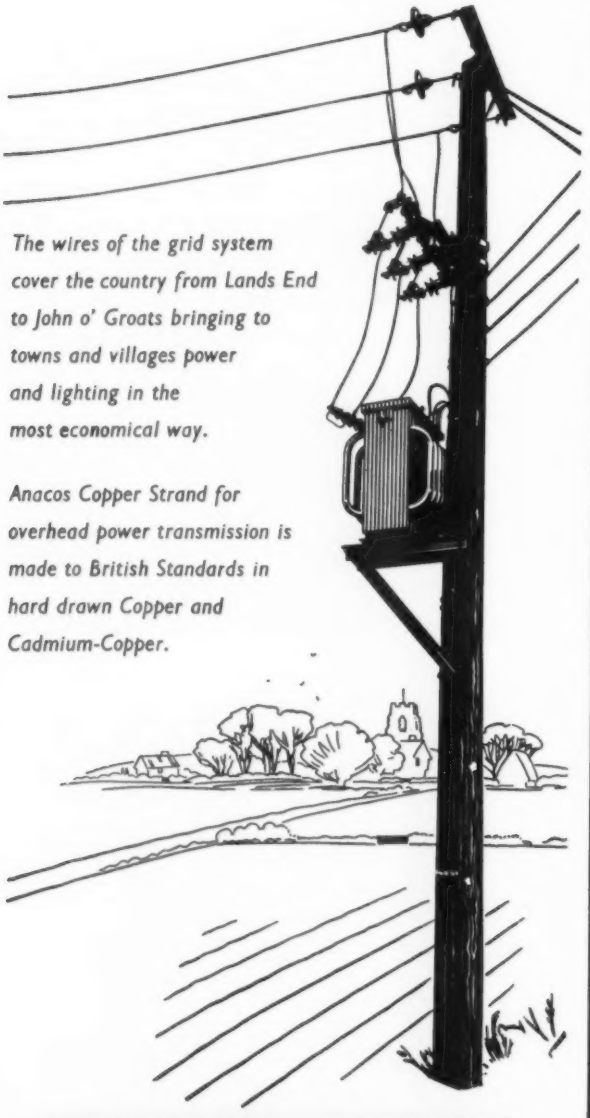
**30-RB**



**RUSTON-BUCYRUS LTD**
**Excavator Specialists**
**LINCOLN**

RUSTON-BUCYRUS

# Power in transit



*The wires of the grid system cover the country from Lands End to John o' Groats bringing to towns and villages power and lighting in the most economical way.*

*Anacos Copper Strand for overhead power transmission is made to British Standards in hard drawn Copper and Cadmium-Copper.*

ANACOS REGD

**copper strand**

**FREDERICK SMITH & COMPANY**

*Manufacturers of "Anacos" Copper and Copper Alloy Conductors*

**ANACONDA WORKS · SALFORD 3 · LANCS.**

**THE RAILWAY GAZETTE**

A journal of Railway Management, Engineering, Operation, and Railway News. It covers every phase of railway activity. It is truly said of this journal that it is "Read wherever there are Railways." *Weekly* 2s. *Annually* £5 *by post.*

**DIESEL RAILWAY TRACTION**

A monthly review of world-wide developments in diesel-engine design, practice, and maintenance and diesel railway traction operation. *Monthly* 2s. 6d. *Annually* 35s. *by post.*

**SHIPBUILDING AND SHIPPING RECORD**

The only publication with direct appeal to both shipowner and shipbuilder. Its world-wide news organisation and technical articles and drawings put it in the forefront of shipping periodicals. *Weekly* 2s. *Annually* £5 *by post.*

**COLLIERY ENGINEERING**

A practical journal dealing with all aspects of coal production; every branch of coal mining technology is reviewed in detail and special attention is given to mechanisation and labour-saving machinery. *Monthly* 2s. 6d. *Annually* £2 *by post.*

**COKE AND GAS**

A technical journal dealing with the scientific and technical problems involved in the production of coke and gas in coke ovens and gasworks. *Monthly* 2s. 6d. *Annually* 35s. *by post.*

**THE RAILWAY MAGAZINE**

A popular magazine containing illustrated articles on Railways and Locomotives. *Monthly* 2s. 6d. *Annually* 35s. *by post.*

**NEW COMMONWEALTH**

Describes and illustrates significant developments in production, trade transportation and related spheres in all countries of the Commonwealth. *Fortnightly* 2s. *Annually* £3 *by post.*

**THE INDUSTRIAL CHEMIST**

A technical journal devoted to the progress of applied chemistry and chemical engineering. It is of vital importance to the chemical manufacturer and all who employ chemical processes in their productive operations. *Monthly* 2s. 6d. *Annually* £2 *by post.*

**ARCHITECTURE AND BUILDING**

A journal for practising and salaried architects, building contractors, designers, and specialists. It deals with the planning, design, construction and the administration of modern building work. *Monthly* 2s. 6d. *Annually* 35s. *by post.*

**WOOD**

"Wood" is the only magazine of its kind. Primarily concerned with the use of wood, it includes articles on trees and timbers, design and construction in all decorative and practical wood usage, machines and machine practice, and trends in world supply. *Monthly* 2s. 6d. *Annually* 35s. *by post.*

**FOOD**

A journal devoted to the manufacture, packaging, and marketing of processed foodstuffs. *Monthly* 2s. 6d. *Annually* £2 *by post.*

**WATER POWER**

A technical journal devoted to the study of all aspects of Hydro-Electric Development. *Monthly* 2s. 6d. *Annually* £2 *by post.*

**MINE AND QUARRY ENGINEERING**

Articles of technical nature cover geology, modern methods of prospecting, the winning of ore and stone, the dressing of ore and minerals, and extraction metallurgy. *Monthly* 2s. 6d. *Annually* 35s. *by post.*

**TOTHILL PRESS LIMITED**

**33, Tothill Street, Westminster, London, S.W.1**

# VALVES & PENSTOCKS

ELECTRICALLY OPERATED

WITH

## HARTLEY "VALECTRIC" HEADSTOCKS

LOCAL OR REMOTE CONTROL

**ALL SIZES UP TO 100 SQUARE FT.**

CIRCULAR OR RECTANGULAR

*ORDERS FROM*

## CEA and LCC

AMONGST OTHERS

## HARTLEYS (STOKE ON TRENT) LTD.

ENGINEERS · STOKE ON TRENT

Please write for our pamphlet P5.

12" SLUICE VALVE
Operated by a
"VALECTRIC" HEADSTOCK

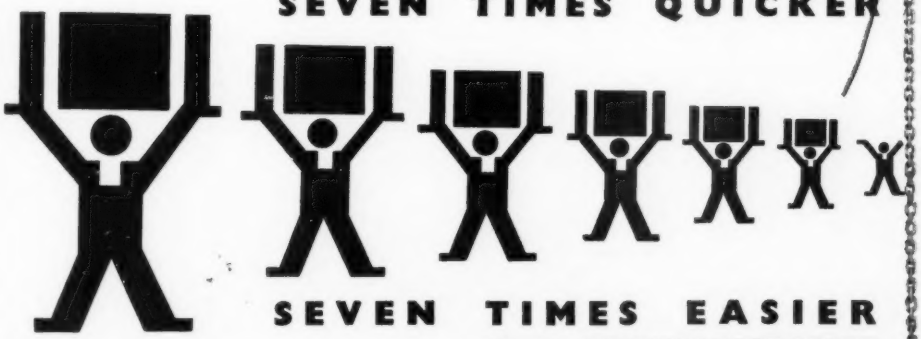
## LOAD by HANDLING

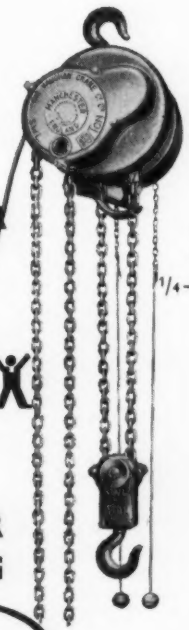
Vaughan

**TYPE CL55 POWERLIFT HOISTBLOCKS**

**is**

**SEVEN TIMES QUICKER**





Five Sizes 1/4—2 tons

**SEVEN TIMES EASIER than MANHANDLING**

Dispatch EX-STOCK

Good Counsel on Lifting Loads from

THE VAUGHAN CRANE CO. LTD.

MANCHESTER 12 ENGLAND

Telephone EASt 2771 (6 Lines)

MAKERS OF FINE LIFTING GEAR SINCE 1880

# INDEX TO ADVERTISEMENTS


**A**

A.C. Plant & Hire Co. Ltd., The ... — 
Acciaieria E Tubificio Di Brescia ... — 
Allgemeine Elektricitäts-Gesellschaft — 
Allis-Chalmers Manufacturing Co. — 
Allmanna Svenska Electriska Aktiebolaget — 
Aluminium Wire & Cable Co. Ltd. — 
Anderson, Grice, The Company, Ltd. ... 64
Andritzer Maschinenfabrik — 
Ansaldo San Giorgio, S.p.A. ... Inside Back Cover
Armfield Hydraulic Engineering Co. Ltd. ... 10
Atlas Copco AB ... 57 & 58

**B**

Balfour, Beatty & Co. Ltd. ... 31
Bell, Theodore, & Co. Ltd. ... 59
Birkett, T. M., Billington & Newton Ltd. ... 36
Blackie & Son Ltd. ... 53
Bochumer Verein ... 43
Bouchayer & Vialett ... 18
Boving & Co. Ltd. ... 5
British Insulated Callender's Cables Ltd. ... 56
British Pitometer, The Co., Ltd. ... 64
British Ropeway Engineering Co. Ltd. ... 4
British Thomson-Hohston Co. Ltd. ... 47
Brown, Boveri & Co. Ltd. ... 16
Bruce, Peebles & Co. Ltd. ... —
Bucyrus-Erie — 
Buss, A.G. — 
Butters Bros. & Co. Ltd. — 

**C**

Canadian Vickers Ltd. — 
Ceretti & Tanfani Ropeway Co. Ltd. — 
Charmilles Engineering Works Ltd. ... 62
Compagnia Generale di Elettricita — 
Compagnie Industrielle de Travaux — 
Consolidated Pneumatic Tool Co. Ltd. ... 60
Craelius Co. Ltd. — 
Crompton Parkinson (Export) Ltd. ... 48

**D**

de Roll, Louis, Ironworks Ltd. — 
Dominion Engineering Co. Ltd. ... 61
Dortmunder Union Bruckenbau, A.G. — 
Drees & Co., G.m.b.H. — 
Dresser Manufacturing Division — 

**E**

Eimco (Gt. Britain) Ltd. — 
ELIN, A.G. ... 45
English Electric Co. Ltd. ... Front Cover
English Steel Corporation Ltd. ... 30
Escher Wyss Ltd ... 9

**F**

Ferguson Pailin Ltd. ... 42
Ferranti Ltd ... 24
Fischer, Ltd., George — 

**G**

Galileo Officine di Battaglia Terme ... 22
General Electric Co. Ltd. ... 8
Gilbert Gilkes & Gordon Ltd. ... 13
Giovanola Freres, S.A. ... 46
Glenfield & Kennedy Ltd. ... 63

**H**

Harland Engineering Co. Ltd., The — 
Hartleys (Stoke-on-Trent) Ltd. ... 67
Henderson, John M. & Co. Ltd. — 
Henley's W. T., Telegraph Works Co. Ltd. — 
Hitachi Ltd. ... 41
Holman Bros. Ltd ... 7
Horseley Bridge & Thos. Piggott Ltd. — 
Huhn, G. ... 38

**I**

Ingersoll-Rand Co. Ltd. ... 11
International Engineering Co., Inc. ... 6

**J**

Jonneret, S.A — 

**K**

Karlstads Mekaniska Werkstad, Akt. ... 39
Krupp, F. — 
Kuljian Corporation, The — 

**L**

Leffel, James & Company, The ... 52
Lepper K. G. Firma Aug. — 
Le Materiel Electrique, S-W — 

**M**

Magrini, S.p.A. — 
Marelli, Ercole & Co., S.p.A. ... 15
Maschinenfabrik Augsburg-Nurnberg, A.G. ... 29
Metropolitan-Vickers Electrical Co. Ltd Outside Back Cover
Michell Bearings Ltd. — 
Mitchell Construction, The Co. ... 17

**N**

Neyrpic ... 51
Newport News Shipbuilding & Dry Dock Co. ... 12
Nuttall Edmund Sons & Co. (London) Ltd. ... 34
Nydqvist & Holm, A/B ... 37

**O**

Oerlikon Engineering Company ... 25

**P**

Painter Bros. Ltd. — 
Pellizari, A., & Figli, S.p.A. ... 50
Pirelli-General Cable Works Ltd. — 

**R**

Ransomes & Rapier Ltd. ... 19
Reyrolle, A. & Co. Ltd. ... Inside Front Cover
Rip Bits Ltd. — 
Riva, Costruzioni Meccaniche ... 35
Ruhrstahl, A.G. — 
Ruston Bucyrus Ltd. ... 65
Ruston & Hornsby Ltd — 

**S**

S. A. Ateliers De Secheron — 
SACE Costruzioni Elettromeccaniche — 
Salvi, A. & Co. — 
Salzgitter Maschinen Aktiengesellschaft ... 21
Scarpa & Magnano — 
Siemens-Schuckertwerke, A.G. ... 54
Smith, A. O. Corporation, International Div. 26 & 27
Smith, Fredk. & Co. ... 66
Smith, S. Morgan Company ... 40
Soc. p. Az. Cementi Armati Ing. Mantelli ... —
Sccieta Nazionale Delle Officine Di Savigliano ... 28
Societe des Forges et Ateliers du Creusot ... —
Standard Telephones & Cables Ltd. — 
Steatite & Porcelain Products Ltd. ... 44
Storey, Thos. (Engineers) Ltd. ... 14
Sulzer Bros. (London) Ltd. ... 23
Svenska Metallverken, A/B — 

**T**

Taylor Tunnicliff & Co. Ltd. ... 33
Technoexport — 
Tees Side Bridge & Engineering Works Ltd. — 
Tokyo Shibaura Electric Co. Ltd. — 
Tosi, Franco, S.p.A. — 

**V**

Vaughan Crane & Co. Ltd. ... 67
Vevey Engineering Works Ltd. — 
Vereinigte Osterreichische Eisen-und Stahlwerke — 
Vickers Armstrongs Ltd. — 
Voith, J. M., G.m.b.H. ... 32
Voith, J. M. (St. Pölten) — 

**W**

Waagner Biro ... 49
Wailes Dove Bitumastic Ltd. — 
Wild, M. B. & Co. Ltd. — 
Wood, Hugh & Co. Ltd. ... 3

**Y**

Yorkshire Electric Transformer Co. Ltd. ... 20



LONDON: Published by TOTHILL PRESS LIMITED, Proprietors of WATER POWER, at 33 Tothill Street, Westminster, S.W.1., and Printed by W. & H. SMITH LTD., Evesham, Worcestershire. *February, 1958*

## COMPLETE HYDRO-ELECTRIC POWER PLANTS

*The "El Nihuil,, power station (93.000 kVA) in Argentina, shown in the illustration, has been entirely designed, manufactured and installed by Ansaldo - San Giorgio.*

**Generators • Transformers • Synchronous condensers • Turbines of all types • Centrifugal and propeller pumps • Mercury rectifiers • Traction equipment • Electric motors of all kinds • Switchgear.**

ANSALDO-SAN GIORGIO
GENOVA
ITALY

ASG

# *Wide waters . . . . .*

*The Kariba Gorge*

*The upstream entrance to the Kariba Gorge, seen from a promontory at the confluence of the Sanyati and Zambesi Rivers.*

THE wide waters of the mighty Zambesi will soon be harnessed to provide power for the development of the vast territory of Central Africa. A dam now being constructed at Kariba will form the largest man-made lake in the world by impounding the waters of the river to provide a controlled flow to the hydro-electric machinery in two power stations.

Metropolitan-Vickers are proud of the leading part they are playing in this development. They are building five 100 MW vertical-type water-turbine-driven generators for the first Kariba Gorge hydro-electric power station of the Federal Power Board of Rhodesia and Nyasaland. These generators will, when installed, be amongst the largest in the world, having an overall diameter of about 40 ft. and weighing approximately 720 tons each.

This company has unrivalled research facilities and manufacturing resources, and is ready to place at your service its technical competence and experience in heavy electrical engineering matters.

METROPOLITAN-VICKERS

ELECTRICAL CO LTD · TRAFFORD PARK · MANCHESTER 17

*An A.E.I. Company*

A/C605